Atlas of Craniomaxillofacial Osteosynthesis

Miniplates, Microplates, and Screws

Franz Härle
Maxime Champy
Bill C. Terry

Thieme

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Preface

Miniplate osteosynthesis without interfragmentary compression is now considered the best treatment for fractures of the mandible. The experimental and clinical investigations that allowed the advantages of this technique to be demonstrated were carried out in Strasbourg by a team drawn from the Department of Maxillofacial Surgery of the Faculty of Medicine, the Higher National School of Arts and Industries, and the Research Group in Bone and Joint Biomechanics of Strasbourg.

This research was purposely limited to the biomechanical study of osteosynthesis of the horizontal body and mandibular angle. It was concluded that the best method of surgical treatment in mandibular fractures was inevitably the result of a compromise in which all the constraints under which the operator works should be taken into account. These include anatomical and physiological conditions, biological requirements with regard to the equipment used, mechanical properties of the mandible and mechanical characteristics of miniaturized equipment set against the forces which are exerted on the bone, surgical imperatives.

The choice of osteosynthesis by small plates in other sectors of facial surgery (such as mandibular condyles, midfacial surgery, and orthopaedic surgery) arises in part from the therapeutic orientation of the surgeon, based on nonexperimental but logical deductions from investigations carried out on the mandible, partly from the convenience that the plates offer, and is finally confirmed by the results obtained.

The improvements in quality of treatment of facial injuries far exceed the expectations that we had following the results of the first biomechanical research in the early 1970s.

The essential objectives of our biomechanical and clinical research were to apply the rigorous principles of modern orthopedic surgery to maxillofacial surgery and to reduce the empiricism which all too often guides the choice of therapy.

I should like to extend my thanks to the engineering students A. Boyoud, J. Patti, B. Sustrac, and J. P. Villebrun as well as to engineering professors Schmidt and Freund from ENSAIS; to Prof. I. Kempf, and Dr. J. H. Jaeger, founder and chief manager, respectively, of the research group at the Centre de Traumatologie, and to Dr. J. P. Loddé, the surgeon responsible for maxillofacial surgery in this team; to Dr. J. M. Schnebelen, a faithful and committed colleague during the long and difficult phase of preparation; and finally to all those young colleagues who enthusiastically accepted and reviewed the technique as well as the new biomechanical drafts, Dr. A. Mariano, Dr. L. G. Gastello, Dr. P. Mercks, Dr. M. J. Rauscher.

Many thanks are owed to all oral and maxillofacial surgeons who have disseminated the concept of miniplate osteosynthesis internationally, both by their convictions and by the quality of their work. They are too numerous for me to name them all individually. Some of them are co-authors of this book, including in particular Prof. Dieter Pape and Prof. Klaus Gerlach, with whom I have enjoyed a prolific scientific cooperation.

Maxime Champy

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Contents

Introduction

In the past intermaxillary fixation has been the traditional method for supporting bone ends in close apposition to allow undisturbed bone healing of fractures of the facial skeleton and also of osteotomies after orthognathic surgical procedures. Although techniques of fracture immobilization utilizing bone plates and screws were described by Lambotte (1913), Warnekros (1917), and Wassmund (1927), it was not until the late 1960s and early 1970s that Hans Luhr (1968), Bernd Spiessl (1969), Wilfried Schilli (1969), and Rüdiger Becker (1973) popularized this technique and introduced methods of bicortical compression utilizing maxiplates and screws for the fixation of mandibular fractures. Such techniques are often utilized in an extraoral approach and open reduction. The basic principles require anatomical reduction, stable internal fixation and a surgical technique causing minimal trauma to achieve early, pain-free mobilization. To allow bicortical screw fixation of the mandible bone, plates have to be positioned at the lower border to avoid damage to the dental roots and also to the inferior alveolar canal. Application of compression plates at the site of compression at the lower border is biomechanically unfavorable resulting in distraction at the area of tension, namely the upper border of the mandible, and also causing distraction in the dental arch. In addition, application of compression to the convex buccal surface of the mandible results in distraction of the fracture on the lingual side which is very difficult to overcome.

Maxime Champy and coworkers (1975) developed the technique of Francois Michelet and A. Moll (1971). He described a method of monocortical fixation using miniaturized plates applied to the narrow surface of the mandible via an intraoral approach. He studied the tension and compression forces of fractured mandibles and found that miniplate application on the tension side of the mandible produced adequate stability to render intermaxillary fixation unnecessary. The technical advantages of miniplate osteosynthesis are as follows: plates are small and easily adapted, they are applied monocortically, the approach is intraoral and they provide functional stability since the system is biomechanically balanced. Subsequently the method has been accepted worldwide.

As a tribute to his home town, Champy founded the Strasbourg Osteosynthesis Research Group (SORG), together with Dieter Pape. SORG comprises an international group of surgeons with a clinical and scientific interest in osteosynthesis techniques. The aims of SORG are to foster scientific development at all levels by controlled clinical studies and research, individual and collaborative publications, continuing educational courses and by the development of new techniques and improved instrumentation to further develop the principle of osteosynthesis in the fields of oral and craniomaxillofacial surgery.

Although miniplate osteosynthesis is directed to the management of mandibular fractures, the principles of osteosynthesis have now been applied to orthognathic surgery, craniofacial surgery, treatment of midfacial fractures, reconstructive bone surgery, and to reconstructive preprosthetic surgery including dental implantology. Although there are many different designs of miniplates and screws used throughout the world, these variants are all based on the original concept developed by Maxime Champy.

This book is written by many surgeons who have extensive experience in osteosynthesis techniques utilizing plates and screws with different systems. For this reason different techniques appear in the text, using different systems devised by Champy. It is for the reader to decide which technique is preferable. This book serves as an atlas of surgical procedures and offers clinical guidelines for using mini and microplate osteosynthesis in the craniomaxillofacial region.

We thank the editorial staff at Thieme International for their professionalism and attention to detail, John Cawood and Peter Ward Booth for checking the English, Andreas Reinhardt for the illustrations, and Verena Hinz for typing the manuscript.

Franz Härle
Bill C. Terry

1 Anatomical Aspects and Biomechanical Considerations

Maxime Champy and Patrick Blez

Monocortical miniplate osteosynthesis is based on precise anatomical considerations and extensive biological and mechanical experiments that have led to the development of specific instruments and hardware.

Anatomical Considerations

The Mandible

Following innovative intraoral miniplate osteosynthesis (Michelet, Deymes, and Dessus, 1973), experimental work and clinical application has demonstrated that monocortical fixation by miniplates is strong enough to withstand the different strains created by masticatory forces (Champy *et al.*, 1975; Champy *et al.*, 1976a, b; Champy *et al.*, 1977; Champy *et al.*, 1978a, b; Champy and Lodde, 1976; Champy and Lodde, 1977; Jaeger, 1978). Because fixation is accomplished by anchoring the miniplates to the bone by means of screws, it is important to know:

- the regions where the bone provides the screws with a firm anchorage; and
- the topography of the dental apices and inferior alveolar nerve to avoid damaging them when inserting the screws.

The outer cortex of the body of the mandible has an average thickness of 3.3 mm, is particularly strong and offers a good anchorage for the osteosynthesis screws. The cortical bone is thicker in the chin region and is reinforced laterally by the oblique line, which runs from the coronoid process to the molar region. In the symphysis region, cross sections of the mandible show the thickest cortex to be at the lower border; behind the third molar, it is stronger at the upper border (Fig 1.1).

Near the alveolar process the thickness of the bone is variable; the anatomy of the tooth roots and the structure of the bone do not allow screw fixation in this region. To avoid damaging the root apices it is safe to place the screws away from the occlusal plane by a distance of at least three times the length of the crown of the tooth.

The inferior alveolar nerve runs in the mandibular canal, from the lingula to the mental foramen, on a concave course. Measurements show that, from back to front, it runs ever closer to the outer cortex and to the lower border. At its lowest point it is 8–10 mm away from the basilar border of the mandible. Although the average thickness of the cortex in that region is 5 mm, it may be less than 3 mm in some cases. About 1 cm before the mental foramen the canal turns upward and forward (Härle, 1977). The foramen lies approximately at the middle of the distance between the alveolar crest and the lower border of the mandible on a vertical line corresponding to the first or second premolar. It is important to remember that the mental foramen sometimes lies higher than the canine apex. Therefore, osteosynthesis in this region involves a certain risk of apical injury.

In most cases the mandibular canal surrounds the neurovascular bundle as a bony tunnel, but sometimes its bony structure is poorly developed. Repeated tests in freshly prepared mandibles have shown that the intrusion of a screw into the canal does not usually cause nerve injury, because the nerve moves away from the instrument (Gerber, 1975). Drilling the holes appears to be

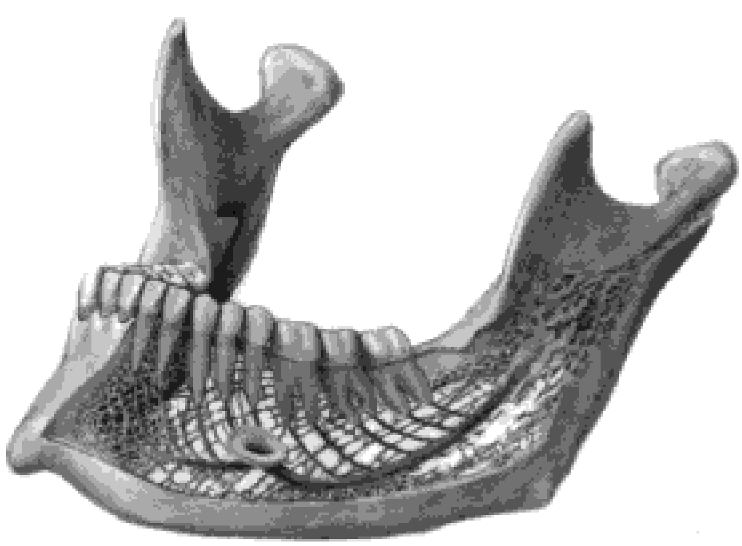


Fig. 1.1 **Lateral view of a mandible.** The lateral and inner cortex of the body of the mandible is taken out

more dangerous to the nerve than inserting the screws.

It should be noted that, with ageing, the alveolar bone atrophies and the structure of the mandible is reduced to the two cortical layers. In edentulous patients the flat upper border of the mandible is composed of sclerous bone, giving poor anchorage for the screws.

One should keep in mind, that in children the mandibular body is occupied by dental germs.

The alveolar bone is covered with attached mucosa. When a fracture occurs, the gum is often lacerated, exposing the mandibular bone to the risk of infection from the oral cavity if treatment is not instituted within 12 hours.

During the first years of life, the blood supply of the mandible depends on the inferior dental artery (Cohen, 1960). Later periosteal vascularization increasingly takes over. In the adult subject, as demonstrated by Bradley (1975), the blood supply relies entirely on the periosteum of the basilar process. This area should therefore be treated with care. Extensive periosteal stripping should be avoided to preserve the blood supply. For this reason a transmucosal approach is preferred to a transcutaneous approach.

The Midface

In the facial skeleton the thickness of cortical bone is variable. Those areas where the cortical bone is thick and therefore suitable for osteosynthesis include the cranium, the nasal bone, the zygomatic bone, the orbital rim, the marginal rim of the piriform aperture and the zygomatic buttress (Mariano, 1978). Elsewhere the cortical bone which constitutes the walls of the various cavities is thin and does not provide a very solid anchorage

Fig. 1.2 **Elective zones of miniplate osteosynthesis.** Favorable regions are colored blue. The red zone is a region where microplates can be used. The green zone is a region where micro- or miniplates can be used

Fig. 1.3 **Localization of the anterior cerebral fossa.** Its deepest point lies 16–20 mm above the frontomalar suture, 5 mm over the tangential line of the upper orbital margin

for osteosynthesis plates, and is only suitable for fixation with microplates (Fig. 1.2).

The frontal bone ranges from 4–9 mm in thickness. The upper orbital margins are particularly well-suited for plate placement, but care should be taken to localize the contours of the frontal sinus. Bone thickness allows placement of 5 mm screws without risking dural penetration. The parietal bone also provides adequate thickness for screw fixation.

The fronto-zygomatic process, which resembles a triangular prism, is made of compact cortical bone and provides an area of excellent purchase for cortical screws. It is covered with a periosteum that is easily elevated, except at the frontomalar suture.

The lateral orbital rim extending to the zygomatic arch provides sufficient bone for screw purchase. The eye should be protected during the operation by using an appropriate retractor. After Champy *et al.*, 1975, the anterior cerebral fossa can be avoided; its deepest point is located 16–20 mm above the frontomalar suture or 5 mm above a horizontal line tangential to the upper orbital margin (Fig. 1.3).

The lower orbital rim is also an area of thick cortical bone. However, because neither muscular force nor any strain is exerted on it, its fixation with a plate seems unwarranted. If isolated fragments require immobilization, absorbable ligatures or microplates are mechanically sufficient.

The maxilla has only two buttresses made of compact and strong bone: the lateral inferior aspect of the piriform aperture (medial or nasomaxillary buttress) and the lateral or zygomatic or maxillary buttress. The importance of these pillars or buttresses was described in 1928 by Sicher and Tandler, by de Brul (1970) and more recently by Manson, Hooper, and Su, 1980. The anterior wall of the maxillary sinus is thin and less suitable as a support for miniplates.

Finally, remember that many cavities exist in this area, some of which contain organs that must be preserved, such as the dura, the eyes and the dental roots. The walls of the frontal, maxillary and ethmoid sinuses, the nasal fossae and the buccal cavity are generally thin and fragile. Protrusion of screws into these cavities should be avoided as there is a risk of causing infection, particularly in the frontal sinus and the nasal cavity.

Biomechanical Principles

The biomechanical principles of monocortical miniplate osteosynthesis are based on mathematical and experimental studies performed in Strasbourg, France, by the Groupe d'Etudes en Biomecanique Osseuse et Articulaire de Strasbourg (GEBOAS). This research work, which concerned the mandible only, resulted in the development of a tension banding osteosynthesis system, able to guarantee fracture healing with neither maxillomandibular fixation nor interfragmental compression. This was achieved as a result of the following considerations and experiments.

Goals

The ideal method of treatment of mandibular fractures is one that establishes a functional therapy by movement. Therefore, it should aim for:

- perfect anatomical reduction;
- complete and stable fixation, allowing painless mobilization of the injured region;
- maintenance of the blood supply of the fragments, of the fracture surfaces and of the surrounding tissues.

The biomechanical requirements for optimal osteosynthesis are:

- the plates and screws must withstand the various stresses due to those tensile and torsional forces to which the mandibular bone is typically subject;
- the plates have to be malleable for easy adaptation to the bone surface, especially in the curved symphysis and molar region, to secure anatomical reduction and to restore perfect dental occlusion;
- the dimensions of the plates should ensure minimal periosteal elevation and fracture site exposure; furthermore, the oral mucosa must be able to cover the plate without any difficulty; and finally
- the size of the screws has to be appropriate for the thickness of the cortex.

Masticatory Stress Distribution in the Mandible

Knowledge of masticatory stresses exerted on the mandible is fundamental because these stresses determine the rational design and positioning of osteosynthesis plates.

The activity of the muscles of mastication can be divided into temporalis forces, masseter forces and reactive biting forces. It is the latter which have the most adverse effects on immobilization of the fracture. These forces vary from patient to patient. By means of strain gauges connected to a Wheatstone bridge, maximal biting forces in young men with healthy teeth were measured. The following values were obtained:

incisor region:	290 N
canine region:	300 N
premolar region:	480 N
molar region:	660 N

The interaction of these muscle forces varies from patient to patient and affects the degree of fracture displacement that must be overcome by treatment.

It is important to understand the distribution of strains created within the mandible as a result of these masticatory forces. Physiologically coordinated muscle function produces tension forces at the upper border of the mandible and compressive forces at the lower border (Weigele, 1921; Winkler, 1922; Motsch, 1968; Küppers, 1971; Boyoud and Paty, 1975; Champy and Lodde, 1976; Tillmann, Härle, and Schleicher, 1983). In addition, Sustrac and Villebrun (1976) and Weigele (1921) demon-

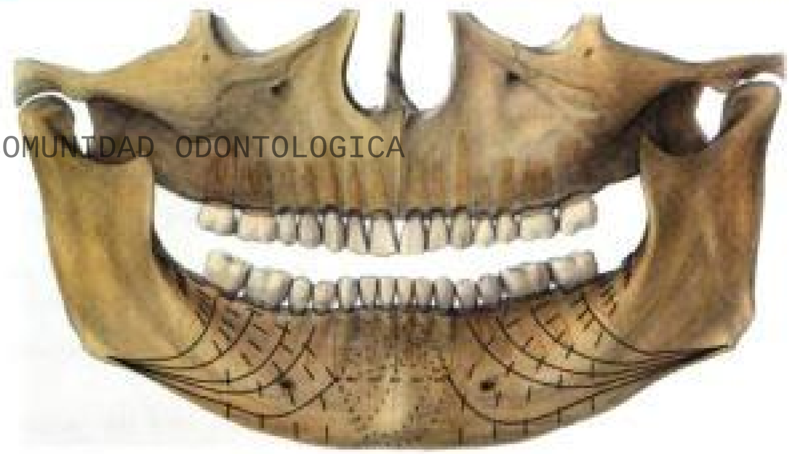


Fig. 1.4 **Forces exerted on the mandible.** Throughout the body of the mandible, biting forces produces tension (dashed line) forces at the upper border and compressive (solid line) forces at the lower border. Torsion forces are produced anterior to the canines (dotted line)

strated that torsion forces are produced anterior to the canines (Fig. 1.4).

In every mandibular fracture these forces cause distraction at the alveolar crest region, accentuated by the degree of trauma and by contraction of the muscles of the floor of the mouth, which can lead to displacement of the fragments. The compressive force at the lower border is a dynamic and physiological force, which is exerted permanently on the fractured fragments along their basilar border (Champy and Lodde, 1976; Ewers and Härle, 1985 a). This compression is due to muscular tonus and increases during masticatory function. When the osteosynthesis is adequately performed, and provided there is no defect in the fracture site, this dynamic compression exactly equals the physiological strains that are exerted on an intact mandible (Champy and Lodde, 1976; Tillmann, Härle, and Schleicher, 1983).

Fig. 1.5 **The ideal osteosynthesis position and ideal osteosynthesis line on the mandibular body**

Definition of an Ideal Osteosynthesis Line on the Mandible

Given the unique anatomy of the mandible, this biomechanical study defines an ideal osteosynthesis line for the mandibular body (see Fig. 1.4). It corresponds to the course of a tension line at the base of the alveolar process inferior to the root apices. In that region a plate can be fixed with monocortical screws, as follows:

- behind the mental foramen the plate is applied immediately below the dental roots and above the inferior alveolar nerve;
- at the angle of the jaw the plate is placed ideally on the inner broad surface of the external oblique line; if this has been destroyed, the plate is fixed on the external cortex as high as possible (Fig. 1.5);
- in the anterior region, between the mental foramina, in addition to the subapical plate, another plate near the lower border of the mandible is necessary to neutralize the torsion forces.

The result of such a monocortical tension-banding osteosynthesis is the neutralization of the distraction and torsion strains exerted on the fracture site, while

Fig. 1.6 **Osteosynthesis position on the mandibular body with a comminuted fracture and a displaced basal triangle segment.** The small fragment may be replaced in anatomic position between larger mandibular segments so that the compressive forces at the lower border can reestablish the physiological strains when the miniplate neutralizes the distraction forces at the upper border. The fracture on the mandibular angle is fixed on the inner surface of the external oblique line

physiological self-compression strains are restored. Interfragmentary compression by means of bicortical screws does not permit this effect. In cases of comminuted fractures it is necessary to apply additional plates to reestablish the physiological strains and to neutralize torsion strains (Fig. 1.**6**).

In the edentulous mandible the correct position of the plate is on the outer cortex of the mandible where the biting forces produce tension forces at the upper border of the mandible. The plate should never be fixed on the upper flat surface where the bone is sclerous (Fig. 1.**7**).

Biomechanics and Principles of Surgical Repair in the Midface

The use of monocortical miniplate osteosynthesis in the cranium and midface, although not based on experimental work, can be considered as a logical extension of this method and is supported by excellent clinical results. The forces exerted on the cranium and facial bones are complex, three-dimensional and difficult to evaluate. They produce various strains on osteosynthesis plates, in every direction, with a preponderance of bending and torsion stresses as opposed to compression forces. The first source of strain is the result of the masticatory forces, lingual pressure and action of masseter and lateral pterygoid muscles. This strain is certainly less important and easier to neutralize than that on the mandible, as demonstrated in 1976 by Champy and Lodde (Fig. 1.**8**).

The technique for midface surgery has evolved directly from orthopedic and reconstructive craniofacial surgery utilizing direct fixation and immediate bone grafting (Tessier, 1967). After occlusion has been reestablished, the principles of repair involve four important concepts. First, reconstruction of the anterior maxillary buttresses is the key to maxillary repair. Second, direct exposure and fixation of these buttresses provides exact anatomical reconstruction. Third, reinforcement of unstable buttresses with miniplates or replacement of comminuted or damaged buttresses with immediate bone grafting will allow reconstruction and stabilization of even the most severe injuries without the need for internal cranial suspension or external fixation devices. Finally, buttress reconstruction will prevent late midfacial collapse or elongation and secondary deformity.

Monocortical miniplate osteosynthesis has proved to be strong enough to withstand all these forces, and to ensure bone healing without interfragmentary compression.

Fig. 1.**7** **Fractured edentulous mandible.** A miniplate has been applied on the upper border of the mandible on the outer cortex. It should not be placed on the superior flat surface of the mandible consisting of sclerous bone

Fig. 1.**8** **The maxillary buttresses.** This shows the two anterior buttresses (medial or nasomaxillary and lateral or zygomaticomaxillary) and the posterior buttress (pterygomaxillary). The relationship of these buttresses to the cranial base and the orbit above, the mandible below and the correct occlusion is seen. Biting forces produce tension (dashed line) forces at the upper border and compressive (solid line) forces at the lower border of the mandible. Torsion forces (dotted line) are produced anterior to the canines of the mandible (see Fig. 1.**4**, 16.**1**)

2 Bone Repair and Fracture Healing

Franz Härle

Structure of Facial Bone

The structure of facial bone is determined by its material properties and by its mechanical role. The bone marrow cavity, the cortex and the spongiosa of the mandible and the midface are similar in their material composition. Their major difference is in the geometric distribution of the bone. The midfacial skeleton consists of thin laminae that provide an increased surface-area to bone-volume ratio as compared with the mandible. Consequently the closer proximity of blood vessels provides a superior supply of nutrients and thus promotes an increased healing rate of the midfacial bones.

Bone is a dynamic tissue, constantly undergoing resorption and remodeling (Schenk, 1992).
The cell types of which it is composed consist of osteoblasts, osteocytes and osteoclasts (Fig. 2.1).

Osteoblasts are derived from pluripotential precursor cells. They produce osteoid, the organic matrix of bone, which is transformed into calcified bone. A layer of 1 µm of osteoid may be produced per day, followed by a maturation phase of 10 days before calcification.

The microscopic structure of osteoid is different in woven and lamellar bone. In woven bone the collagen fibrils are randomly orientated and have a felted texture. In lamellar bone they are arranged in parallel bundles. Woven bone mineralizes immediately after osteoid deposition. In fracture healing, woven bone is transformed into lamellar bone.

Osteocytes are derived from osteoblasts. Sometimes osteoblasts can stop producing osteoid. They transform into osteocytes, which are connected with the deeper osteocyte cell layers. The osteocytes lie between the concentric lamellae.

Osteoclasts are multinucleate giant cells derived from mononuclear macrophages. Osteoclasts have a specialized role of bone breakdown. This activity is limited to Howship's lacunae. Howship's lacunae are small subcellular chambers with a low pH. The pH is maintained by hydrochloric acid, which dissolves the mineral. The organic matrix is degraded by proteases and collagenases. Osteoclasts are able to resorb 50–100 µm of bone per day.

Osteons are cylindrical vascular tunnels formed by an osteoclast-rich tissue. They contain pluripotential pre-

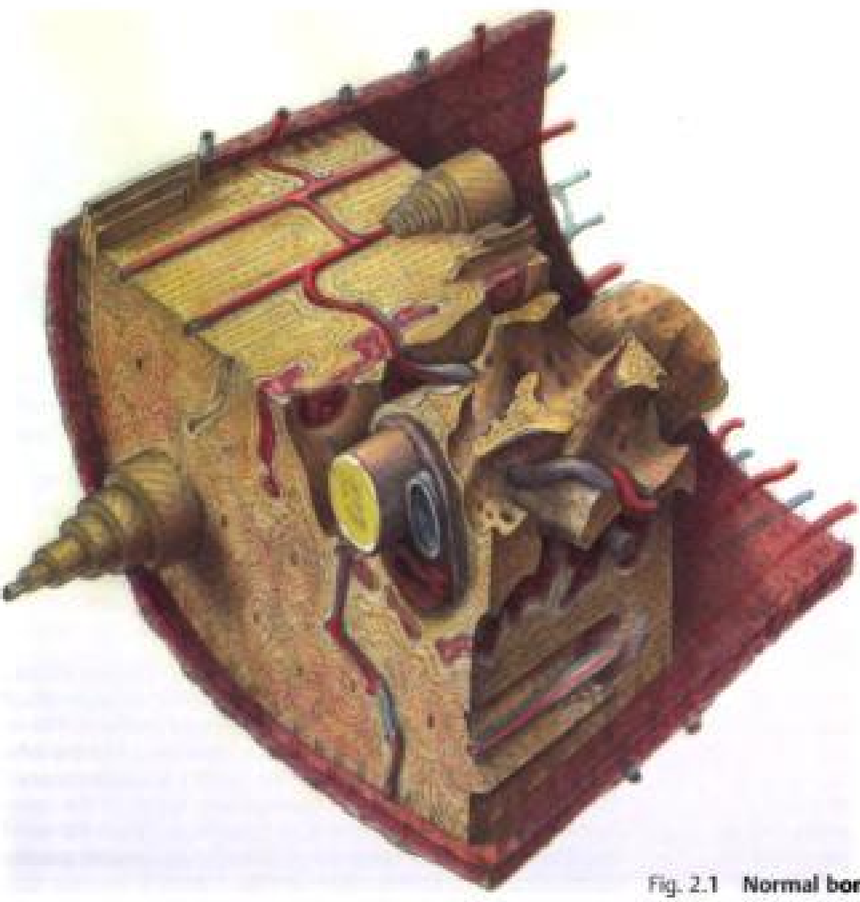


Fig. 2.1 **Normal bone structure**

cursor cells and endosteum known as the cutting cone. The bone removed by the cutting cone is replaced by osteoblast-rich tissue, known as the closing cone. This forms concentric layers of lamellar bone which surround the vascular haversian canal. Volkmann canals also contain nutritional vessels arising from the periosteal and endosteal bone surface which connect with the haversian vessels within the osteons (Schenk and Willenegger, 1964). The size of the osteonal transport system is 100 µm which limits the width of an osteon to approximately 200 µm. The mean width of a lamella is 3–7 µm (see Fig. 2.1).

The three most important conditions necessary for bone formation and bone mineralization are pluripotential precursor cells, ample blood supply and mechanical rest (Pauwels, 1940).

Fracture Healing

There are two types of fracture healing, namely indirect and direct bone-healing. Direct bone- healing is a synergism between contact and gap healing. Indirect bone-healing occurs via the pluripotential cells located within the cortical and cancellous bone periosteum and associated soft tissue. Indirect bone-healing results from the mechanical instability of the fracture, caused by resorption of fracture ends and callus formation.

In the case of direct bone-healing the close apposition of the fracture segments provides mechanical stability. Consequently the osteons of the fracture end are in direct contact, allowing transverse bridging of the haversian system with no intervening callus formation (Fig. 2.2).

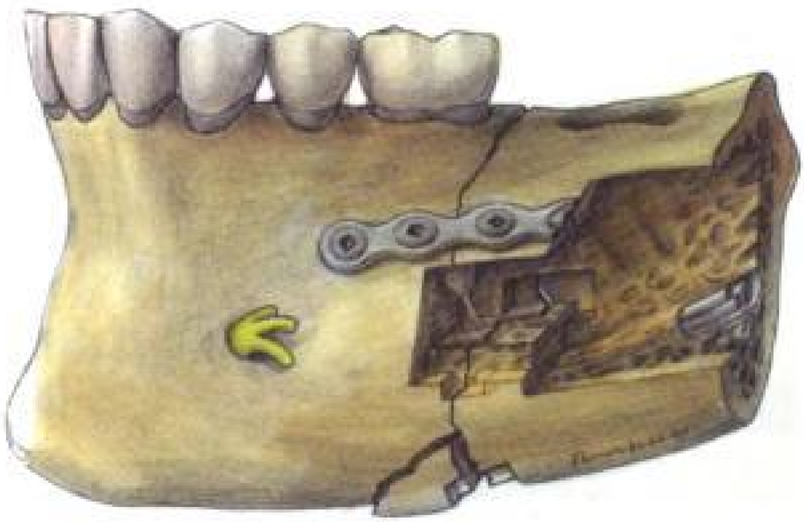


Fig. 2.2 **Three windows in a mandibular fracture with miniplate osteosynthesis on the tension side.** This shows indirect bone-healing in the window on the inferior border of the mandible with the mobile fragment; direct bone-healing in the window of the lateral cortex of the mandible by contact healing after perfect and anatomical reduction; direct bone-healing in the window of the inner cortex of the mandible by gap healing

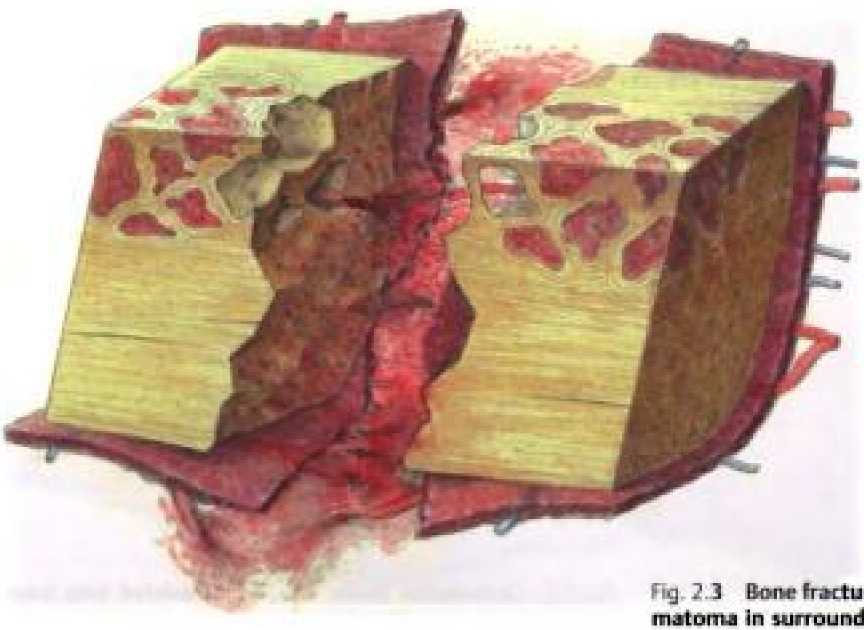


Fig. 2.3 **Bone fracture with rupture of blood vessels and hematoma in surrounding soft tissues**

Indirect Bone-Healing (Secondary Osseous and Soft Tissue Healing)

Bone fracture leads to the rupture of blood vessels with hematoma formation in the surrounding soft tissues and localized avascularity of the fragment ends. Further complications are thrombosis of the vessels within the haversian and Volkmann's canals a few millimeters from the ends of fragments (Fig. 2.3). Indirect bone-healing occurs via callus formation, as seen in some cases of spontaneous bone-healing, with or without direct fixation of the fracture site.

A number of stages of callus formation can be distinguished. Initially the formation of periosteal callus leads to a decrease in interfragmentary strain, which is followed by interfragmentary and endosteal callus formation. Invading granulation tissue replaces the initial hematoma and is transformed into interfragmentary connective tissue (Fig. 2.4). The ends of the fragments are resorbed by osteoclasts (Figs. 2.4, 2.5). The more interfragmentary connective tissue is remodeled into fibrocartilage (Fig. 2.6). Since fibrocartilage is more rigid than fibrous tissue, the interfragmentary tissue becomes stiffer and increases the resistance to motion of the frag-

Fig. 2.4 **Granulation tissue replaces the initial hematoma in the bone fracture, and the ends of the fragments will be resorbed by osteoclasts.** Hematoma is shown only in the inferior part of the bone fracture

Fig. 2.5 **Granulation tissue will be remodeled into interfragmentary connective tissue**

ments. Subsequently the fibrocartilage undergoes mineralization. Vascular invasion of fibrocartilage is combined with resorption of mineralized matrix. Calcified fibrocartilage must undergo resorption before osteoblasts can start to produce osteoid as a base for new bone deposition (Fig. 2.7). Initially the calcified fibrocartilage is replaced by woven bone. After the fracture is bridged by woven bone, stability is obtained and function is possible (Philipps and Rahn, 1992). Haversian remodeling proceeds, replacing woven bone with lamellar bone (Fig. 2.**8**).

Fig. 2.6 **Interfragmentary connective tissue will be remodeled into fibrocartilage**

Fig. 2.7 **Calcified fibrocartilage must be partially resorbed before osteoblasts can start to produce osteoid**

Fig. 2.8 **Haversian remodeling begins to reconstruct the lamellar direction of the bone**

Fig. 2.9 **Cutting cones are able to cross the interface from one fragment to the other by remodeling the haversian canal**

Direct Bone-Healing (Primary Osseous Healing)

Direct bone-healing was first described in radiographs after perfect anatomic repositioning and stable fixation. Its features are lack of callus formation and disappearance of the fracture lines. Danis (1949) described this as *soudure autogène* (autogenous welding). Callus-free direct bone-healing requires what is often called 'absolute stability by interfragmentary compression' (Steinemann, 1983). In the craniomaxillofacial skeleton, interfragmentary compression for direct bone-healing is not necessary as demonstrated by Ikemura *et al.* (1984), Ewers and Härle (1983, 1985) experimentally, and by Champy and Lodde (1977), and Kahn and Khouri (1992) clinically. Schenk and Willenegger (1963, 1964) described two different forms of direct bone-healing, contact healing and gap healing.

Contact healing of the bone means healing of the fracture line after stable anatomic repositioning with perfect interfragmentary contact and without the possibility for any cellular or vascular ingrowth. Cutting cones are able to cross this interface from one fragment to the other by remodeling the haversian canal. Haversian canal remodeling is the main mechanism for restoration of the internal architecture of compact bone (Fig. 2.**9**). Contact healing takes place over the whole fracture line after perfect anatomical reduction, osteosynthesis and mechanical rest (Fig. 2.**10**). Contact healing is only seen directly beneath the miniplate (see Fig. 2.**2b**).

Gap healing takes place in stable or 'quiet' gaps with a width greater than the 200 µm osteonal diameter. Ingrowth of vessels and mesenchymal cells starts after surgery. Osteoblasts deposit osteoid on the fragment ends without osteoclastic resorption. The gaps are filled exclusively with primarily-formed transversely-orientated lamellar bone. Replacement is usually completed within 4 to 6 weeks (Fig. 2.**11**). In the second stage, the transversely- orientated bone lamellae are replaced by

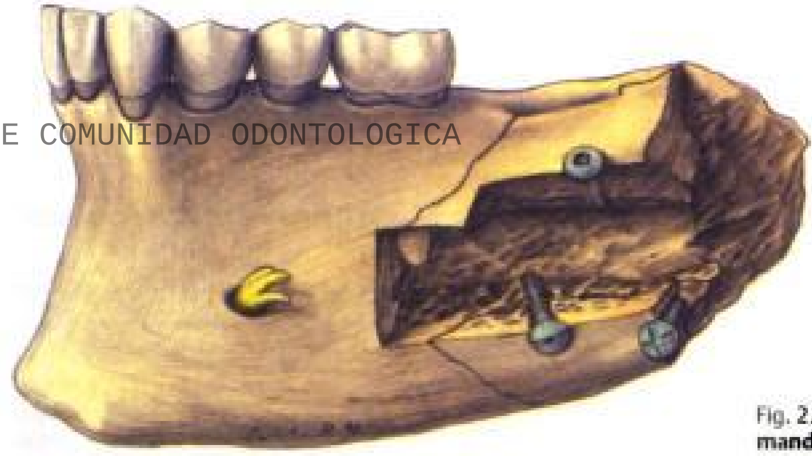


Fig. 2.10 **Perfect anatomical repositioning of a mandibular fracture by lag screw osteosynthesis**

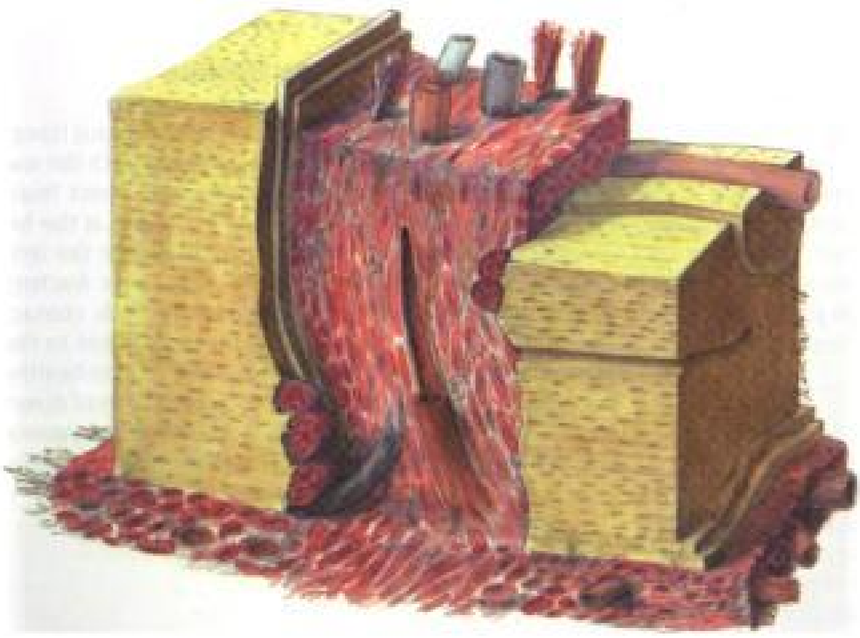


Fig. 2.11 **Osteoblasts deposit osteoid and the gaps are filled with primary formation of transversely-orientated lamellar bone**

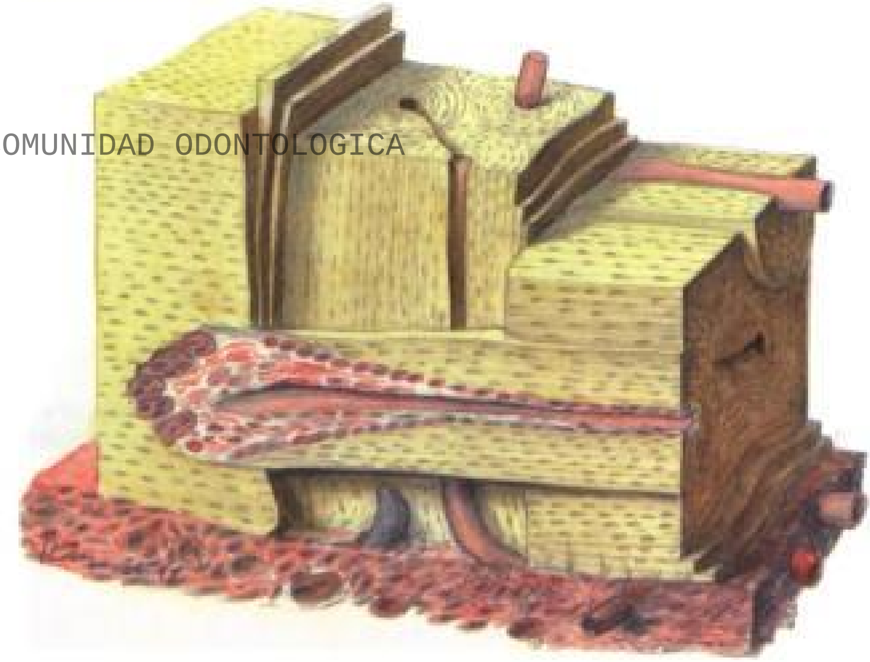


Fig. 2.12 **Haversian remodeling.** Transversely-orientated bone lamellae are replaced by axially-orientated osteons

axially-orientated osteons, a process which is referred to as haversian remodeling (Fig. 2.**12**). After 10 weeks the fracture is replaced by newly-reconstructed cortical bone. Gap healing is seen, for example, on the inner side of the mandible after miniplate osteosynthesis. Gap healing plays an important role in direct bone-healing. Gaps are far more extensive than contact areas. Contact areas, on the other hand, are essential for stabilization by interfragmentary friction. Contact areas protect the gaps against deformation. Gap healing is seen far from the plate (see Fig. 2.**2c**).

Pseudoarthrosis

Pseudoarthrosis describes the nonunion caused by the failure of tissues to differentiate. Tissue differentiation is not possible if, for example, there is movement of the fracture ends due to excessive external forces. In these cases stabilization is required. When interfragmentary resorption has progressed so far that bony union is not possible, then bone grafting is necessary.

Craniomaxillofacial Bone-Healing

Bone repair and fracture healing to restore original integrity (*restitutio ad integrum*) can be achieved with the use of miniplates and screw fixation to provide direct healing. In the mandible, the plate must be placed at the biomechanically most favorable site to neutralize the tension forces and torsional moments that cause fracture distraction. Bone plate fixation provides both contact and gap healing. Contact healing is seen adjacent to the plate and between lag screw osteosynthesis. Gap healing occurs remotely from the plates. A combination of direct and indirect healing also occurs in the maxilla, zygoma, naso-ethmoid and cranium regions following the principles of miniplate osteosynthesis.

3 Surgical Approaches

Franz Härle

Biomechanical Principles

The surgeon is encouraged to regain the maximum function of injured skin or mucosa with the least possible deformity and scarring. The ultimate appearance and function of a scar can be predicted by the static and dynamic skin tensions on the surrounding skin (Thacker *et al.*, 1975). Static tension lines exist within the skin and are oriented in specific but variable directions throughout the body. This was first recognized by Dupuytren in 1834. He examined a suicide victim who had sustained three self-inflicted puncture wounds made by an awl. He noted that the skin incisions either gaped apart or remained closed in a consistent way, depending on the direction of the incision and their site on the body.

In 1861 and 1862 Langer examined the skin of cadavers which were lying in a normal anatomic position. He inserted an awl to depths of 2 mm and 2.5 mm and so identified the direction of predominant tension. These static lines of maximal skin tension are now known as Langer's lines (Fig. 3.1).

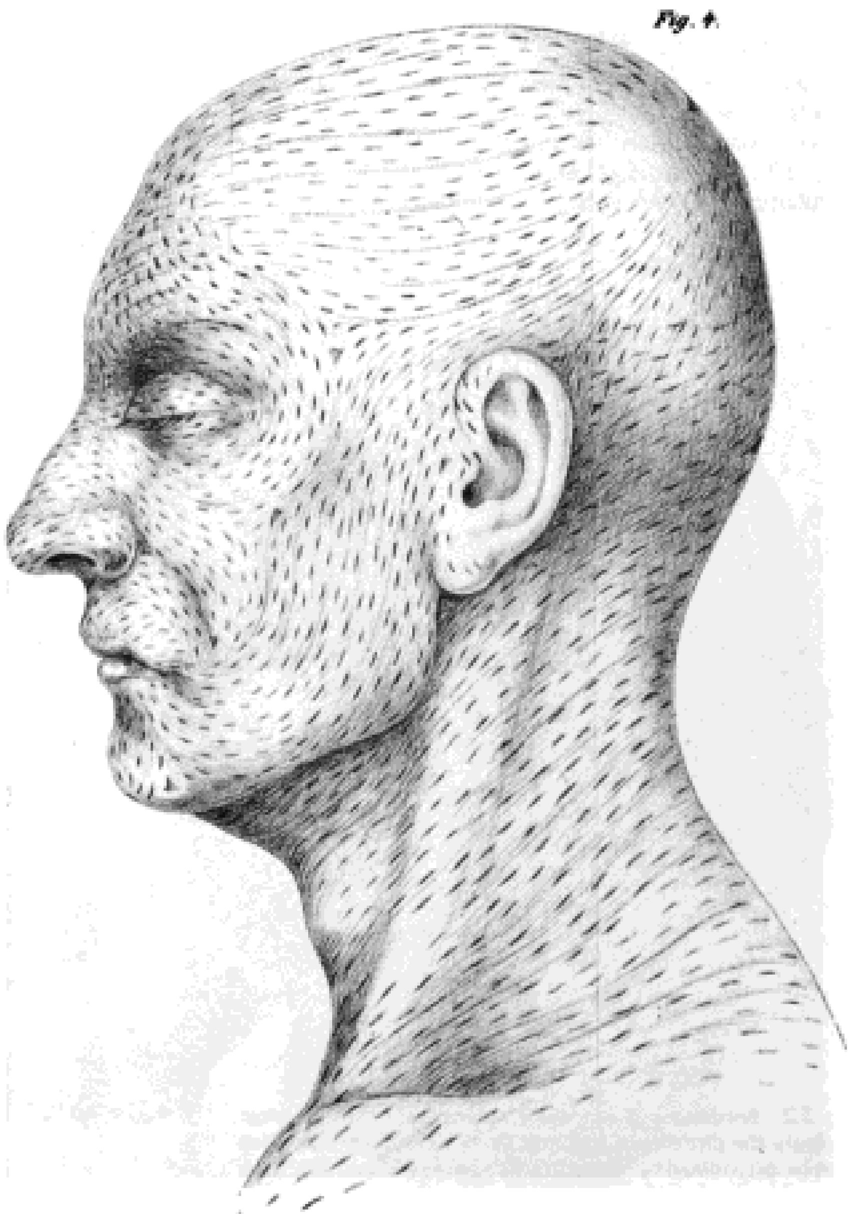


Fig. 3.1 **Langer's lines were noted after puncturing the skin of cadavers with a sharp awl.** (Langer, 1861; Fig. 4)

Extraoral Incision

Kocher in 1892 was the first surgeon who recognized the surgical significance of Langer's lines. He recommended that surgical incisions should be made in such a way as to follow the direction of Langer's lines to obtain the best postoperative scars. This recommendation was reinforced by Kraissl (1951). However, Borges and Alexander (1962), while recognizing the importance of Langer's lines, disputed their biological relevance, since they represented the lines of skin tension following rigor mortis. They observed that in the living body in a relaxed state, skin tension occurred in one specific direction (Fig. 3.2). They called this phenomenon 'relaxed skin tension lines' (RSTL). On the face, Borges, Alexander, and Block (1965) distinguished four principal relaxed skin tension line directions:

- the facial median line;
- the nasolabial line;
- the palpebral line; and
- the marginal facial line.

Borges (1973) recommended that, to obtain optimal healing of scars, the surgical incision should follow the relaxed skin tension line direction within these areas (Fig. 3.3). Skin tension lines are usually oriented perpendicularly to the underlying muscles (Fig. 3.4).

Fig. 3.2 **Borges and Alexander's 'relaxed skin tension lines' indicate the directional pull that exists in relaxed skin.** They jcan be determined by noting the 'furrows and ridges' which are formed by pinching the skin. (after Albrecht Dürer, *Angel Head*, 1506, Albertina, Vienna)

Fig. 3.3 **The four principal relaxed skin tension lines.** The facial median line, the nasolabial line, the palpebral line and the marginal facial line. (after Albrecht Dürer, *Portrait of an 18 year old lad*, 1503, Bibliothek der Akademie der Künste, Vienna)

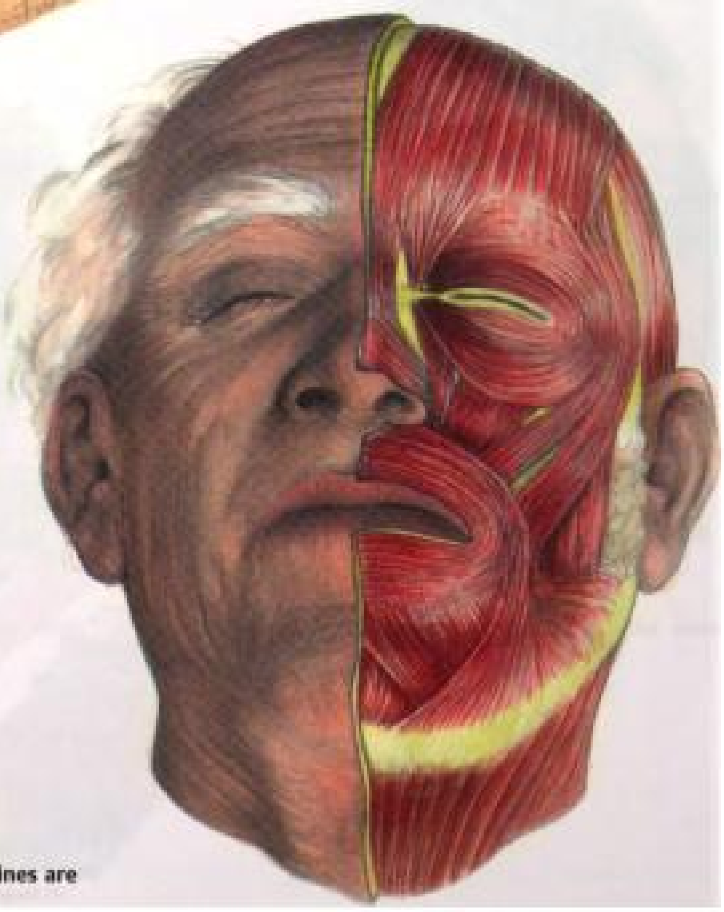


Fig. 3.4 **Facial skin tension lines and facial muscle lines are usually orientated perpendicularly to muscles**

Today it is generally recognized that the aesthetically best results in the face are obtained if the long axis of the scar lies in the direction of the maximal skin tension (Remmert *et al.*, 1994). The more closely a wound follows the relaxed skin tension lines, the better is the cosmetic result.

Utilization of an extraoral approach for mini or microplate and screw application is rare. However, in some cases an extraoral approach (such as the classical submandibular, lower eyelid, upper lid blepharoplasty, brow and coronal approaches) is required (Fig. 3.**5**). When such an approach is used, the facial nerve is potentially at risk and therefore the surgeon must be aware of and consider the relevant anatomy (Fig. 3.**6**).

Fig. 3.**5** **Preferred surgical approaches to the facial skeleton.** (after Albrecht Dürer, *St. Apollonia*, 1521, Kupferstichkabinett, Berlin)

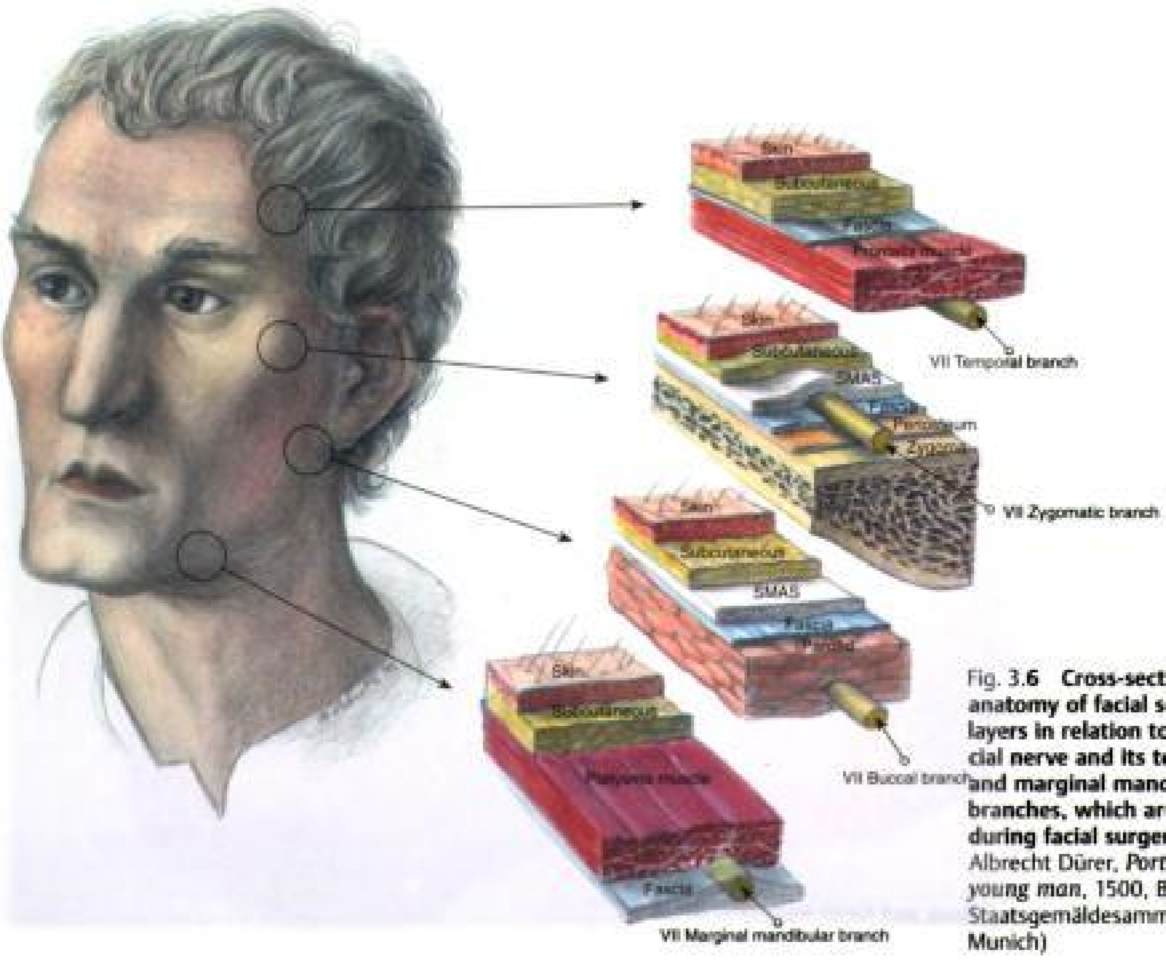


Fig. 3.**6** **Cross-sectional anatomy of facial soft tissue layers in relation to the facial nerve and its temporal and marginal mandibular branches, which are at risk during facial surgery.** (after Albrecht Dürer, *Portrait of a young man*, 1500, Bayrische Staatsgemäldesammlungen, Munich)

Intraoral Incisions

The typical intraoral incision lines for exposure of either the maxilla or the mandible are made within the unattached mucosa 4–5 mm below the level of the attached gingiva (Figs. 3.**7**, 3.**8**).

Alternatively, to reduce scar tissue formation and minimize the risk of infection, the marginal rim incision can be used (see Figs. 3.**7**, 3.**8**). To expose the posterior part of the mandible the incision line is placed directly over the ascending ramus of the mandible. For the edentulous patient the incision line for exposure of the maxilla and the mandible is usually on the crest of the alveolar ridge (Figs. 3.**9**, 3.**10**).

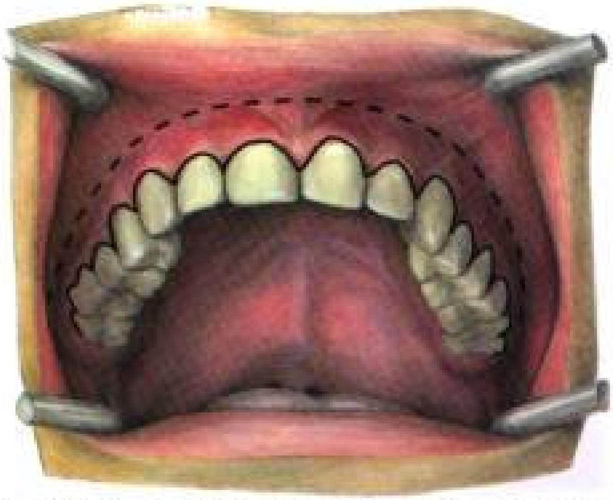


Fig. 3.**7** **Intraoral incision for exposure of the maxilla.** Usually, this is made in the unattached mucosa 4–5 mm below the level of the attached gingiva (dashed line). Alternatively the marginal rim incision (solid line) can be used.

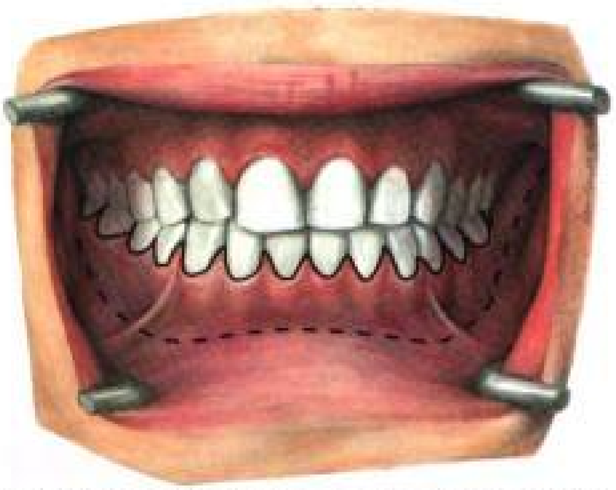


Fig. 3.**8** **Intraoral incision for exposure of the mandible.** Details as in Fig. 3.**7**

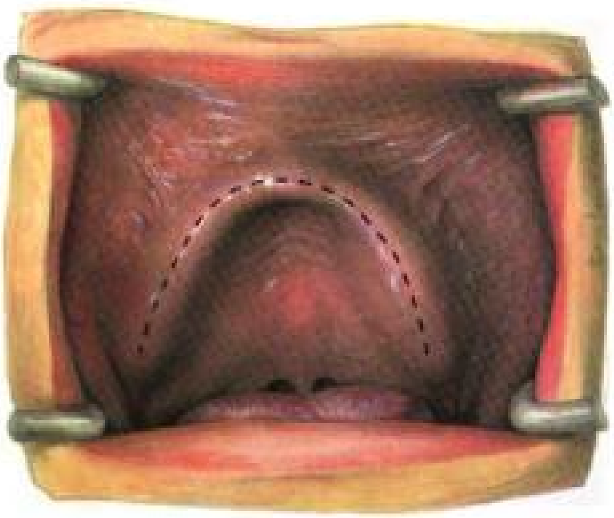


Fig. 3.**9** **Intraoral incision for exposure of the edentulous maxilla is the crest of the alveolar ridge**

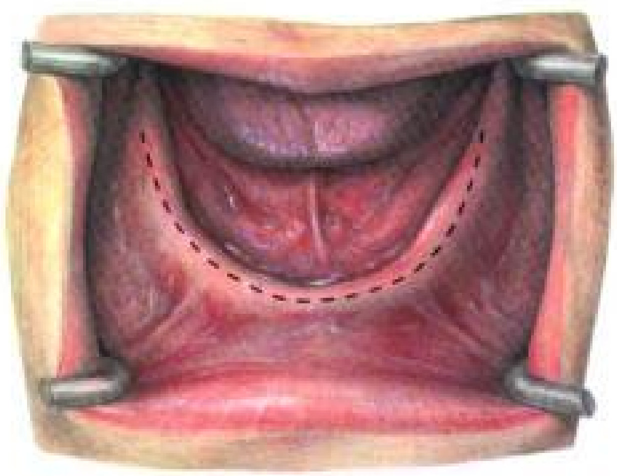


Fig. 3.**10** **Intraoral incision for the exposure of the edentulous mandible is the crest of the alveolar ridge**

Mandible

Mandible Intraoral Vestibular Approach

Depending on the fracture line an incision is made following the oblique line and is continued forward, 4–5 mm below the attachment of the mucosa and gingiva. The incision is only carried through the mucosa. The following, second incision is made at right angles to the underlying bone and carried down through the submucosa, muscles and periosteum (Fig. 3.**11**). Care must be taken to avoid injury to the mental nerve. The nerve has to be identified during the subperiosteal dissection. If exposure of the neurovascular bundle is necessary, an incision has to be made through the periosteum over the mental nerve (Fig. 3.**12**). After dissection of the neurovascular bundle the mandible can be exposed. The dissection has to be carried out inferiorly enough to allow adequate application of the fixation system. The periosteum should be handled with care and should not be elevated excessively. The extension of the incision should not be as small as to prevent wound dehiscences caused by local trauma. The closure of the wound can be performed in two layers. The first layer is usually a resorbable, horizontally-running mattress suture. The closure of the second layer is performed in a simple continuous fashion. When only one suture layer is preferred, the closure should be performed by placing the suture through mucosa, muscles and periosteum.

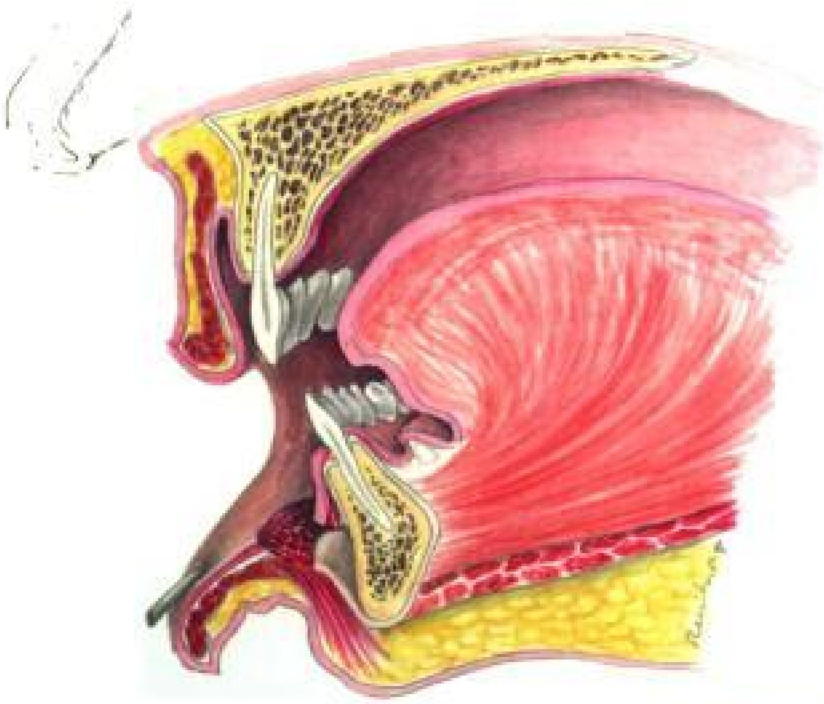


Fig. 3.11 **Cross-sectional view of the vestibular approach to the mandible.** Mucosa, submucosa, muscles, and periosteum are incised

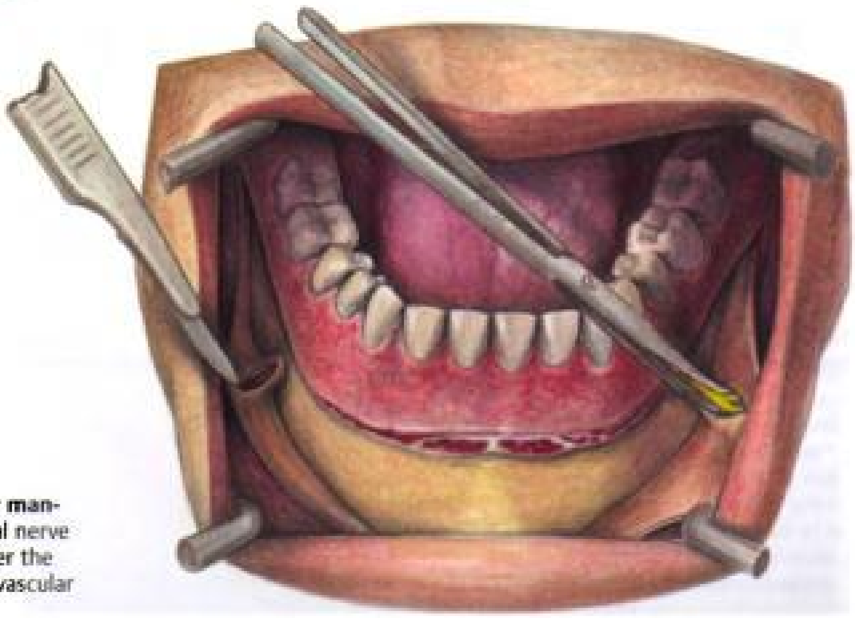


Fig. 3.12 **Frontal view of the vestibular mandibular approach.** Exposure of the mental nerve by an incision through the periosteum over the mental nerve and dissection of the neurovascular bundle

Mandible Intraoral Marginal Rim Incision

For exposure of the alveolar crest or treatment of traumatized teeth, then protection of lacerated mucosa is preferred. This can be achieved by using the marginal rim incision which allows direct elevation of the underlying periosteum without involving incisions into the overlying mucosa, submucosa, muscle, and periosteal layers (Figs. **3.13**, **3.14**). Wound healing is excellent,without visible scarring (Kerscher, Soofizadeh, and Kreusch, 1995; Kreusch, Fleiner, and Steinmann, 1993).

Mandible Combined Intraoral–Transbuccal Approach

For fixation of screws or plates at the angle of the mandible it may be necessary to expose the mandible by an intraoral–transbuccal approach. First the mandible is exposed by an intraoral approach. For transbuccal drilling, tapping and screw insertion a stab incision is made through the skin overlying the plate. The incision should follow the relaxed skin tension lines. Next the transbuccal trocar is inserted and a transbuccal tunnel is established. The trocar is removed and a cheek retractor is inserted.

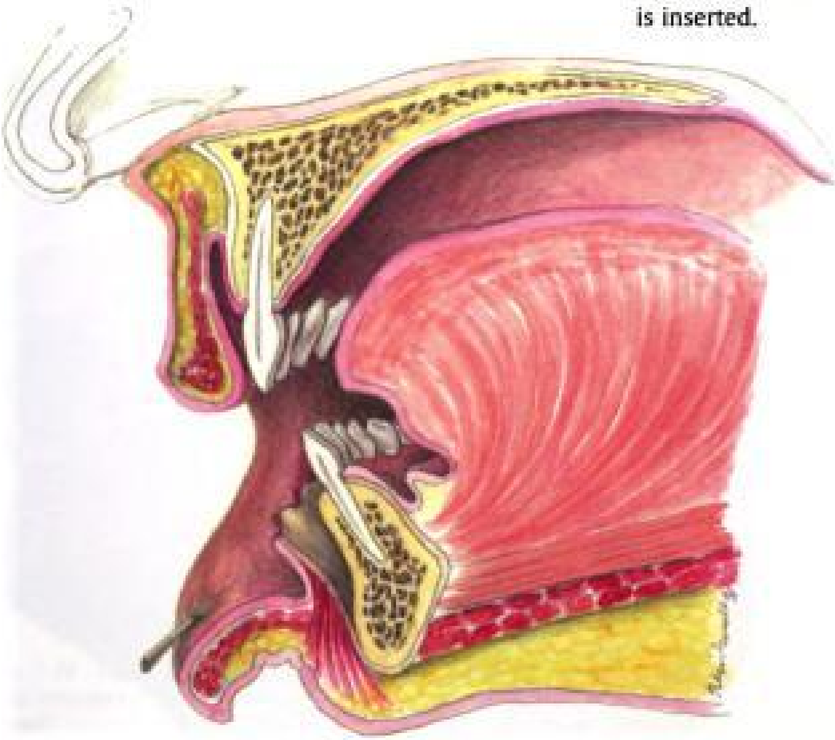


Fig. 3.**13** **Cross-sectional view of the marginal rim approach to the mandible.** Incision of the mucosa, submucosa, muscles, and periosteum is not necessary

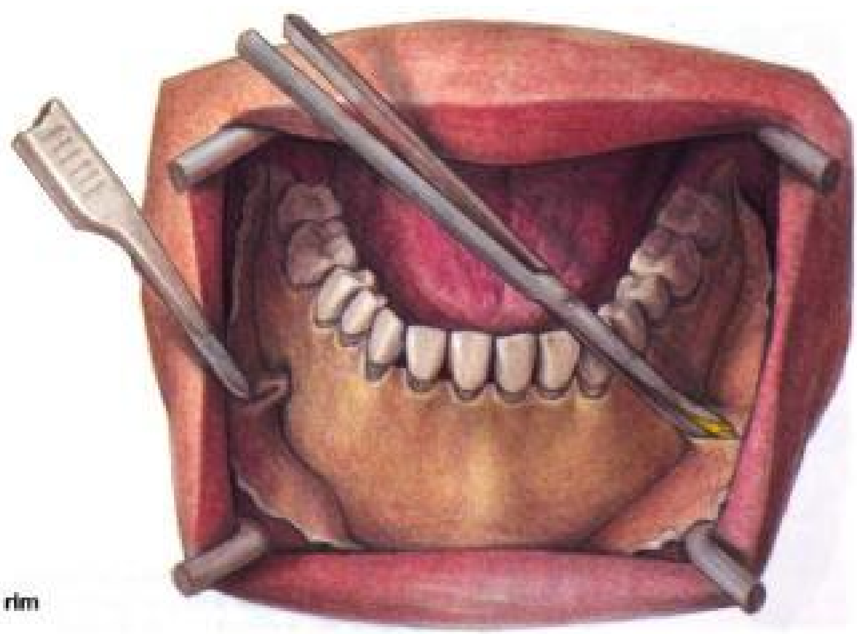


Fig. 3.**14** **Frontal view of the marginal rim approach to the mandible**

Mandible Extraoral Submandibular Approach

This incision should be made in a natural skin crease at a level approximately two finger breadths below the inferior border of the mandible. Skin and subcutaneous tissue is incised to the level of the platysma muscle, which is incised at right angles to the muscle fibers. The dissection continues superiorly towards the inferior border of the mandible. The marginal mandibular branch of the facial nerve is closely related and must be identified immediately beneath the platysma muscle. Alternatively the dissection can be developed through the deep cervical fascia at the level of the submandibular gland. The capsule of the gland is identified and the overlying facial vein and artery are ligated. The marginal branch of the facial nerve lies superior to these vessels and is therefore not endangered by this approach (Figs. **3.15**, **3.16**).

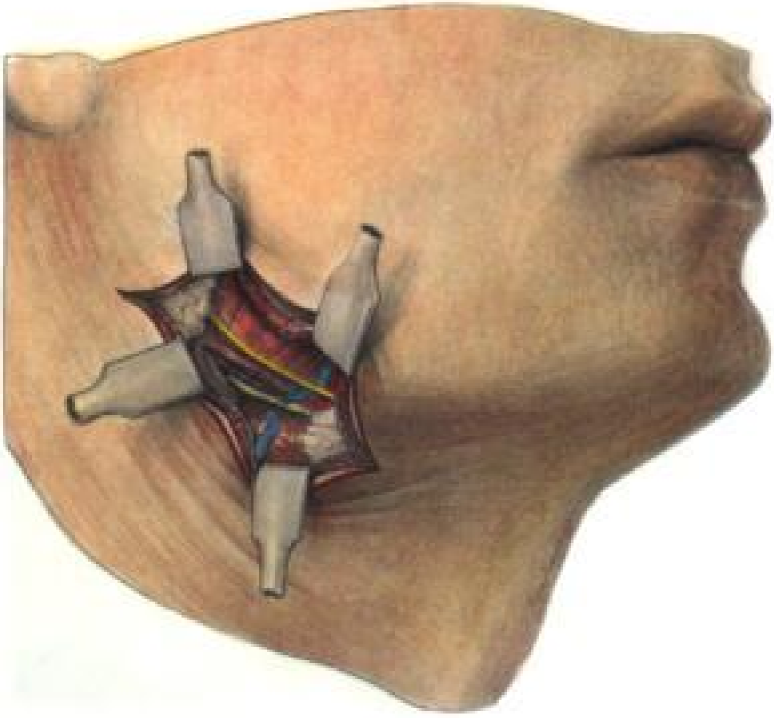


Fig. 3.**15** **Extraoral submandibular approach**

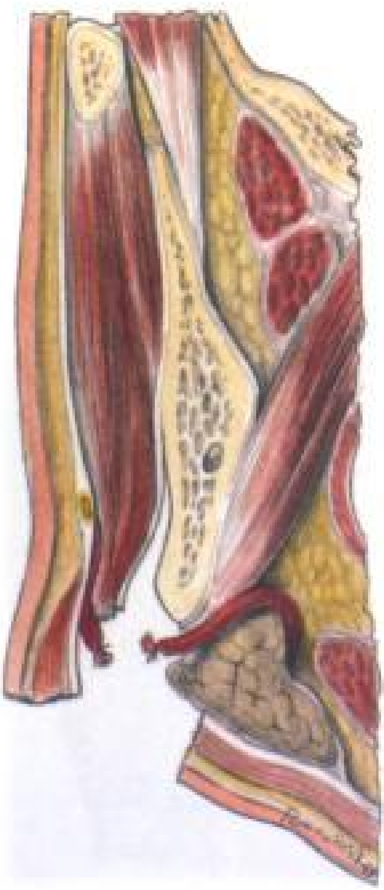


Fig. 3.**16** **Cross-sectional view of extraoral submandibular approach.** The facial artery is ligated and turned up for preservation of the marginal branch of the facial nerve

Eckelt (1991) developed a technique for lag screw osteosynthesis of condylar fractures. A skin incision is made 1 cm superior to the inferior border of the mandible and extended to the level of the platysma muscle. Then the facial nerve is identified using a nerve stimulator. The masseter is incised superior to the facial nerve and reflected inferiorly which avoids risk of damage to the facial nerve (Figs. 3.17, 3.18).

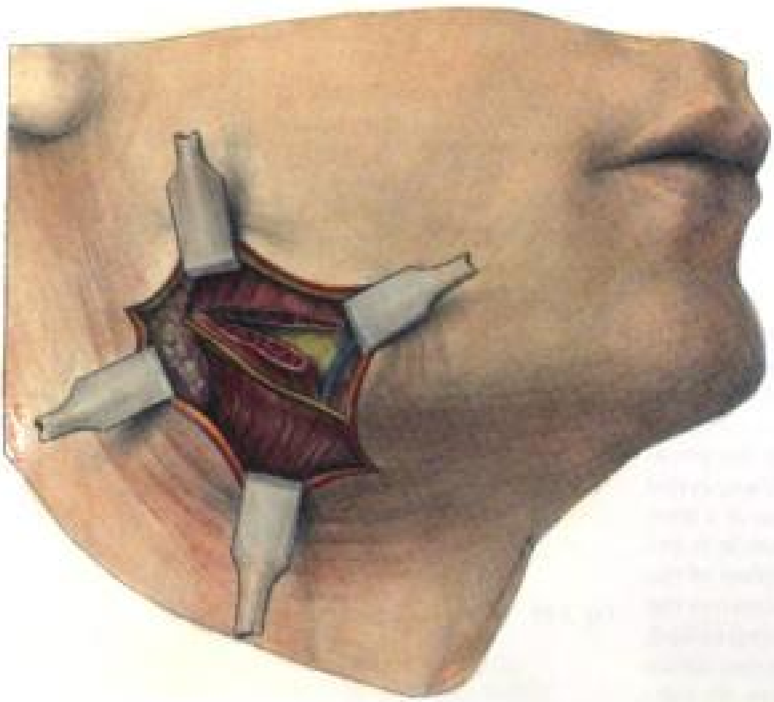


Fig. 3.17 **Eckelt's approach for exposure of the mandible.** The masseter is incised superior to the facial nerve and turned down

Fig. 3.18 **Cross-sectional view of Eckelt's approach**

Mid and Upper Face

Maxilla Intraoral Vestibular and Marginal Rim Approach

As already described for the mandible, exposure of the maxilla can be achieved by either a vestibular or marginal rim incision. In this way the lower half of the midface including the infraorbital rim can be exposed. A common complication of the vestibular incision is wound dehiscence. Such a dehiscence can be avoided with a marginal rim incision, which also offers enhanced healing due to the immunological defense mechanism of the periodontium (Schroeder and Page, 1977).

Lower Eyelid

The lower orbital rim and orbital floor can be exposed transcutaneously through subciliary, lower eyelid, or infraorbital incisions. In the transconjunctival approach the incision is limited by the fornix. For more extensive exposure a lateral canthotomy and cantholysis are necessary. According to Bär *et al.* (1992) the lower eyelid incision showed the best results, with a lower complication rate compared to other approaches. The lower eyelid incision is placed parallel to the ciliary margin at a level just caudal to the tarsus. The orbicularis muscle is exposed and, with blunt dissection in the direction of the muscle fibers, the orbital septum is exposed down to the infraorbital rim. After the orbital rim has been identified, an incision is made from the facial side of the rim, above the infraorbital nerve, through the periosteum. By subperiosteal dissection the orbital floor and the infraorbital rim will be exposed above the infraorbital nerve (Fig. 3.**19**). After osteosynthesis the periosteum is approximated and the skin is sutured without subcutaneous sutures.

Fig. 3.**19** **Lower eyelid approach**

Upper Lid Blepharoplasty Approach

The upper lid blepharoplasty approach provides an excellent access to the frontozygomatic suture with good aesthetic results. This technique has been popularized by Kellmann and Marenette (1995) and Kung and Kaban (1996). The incision is placed in an upper lid skin crease extending from the mid pupil level to the lateral orbital rim. As usual in the orbital region hemostasis is obtained with bipolar cautery and not monopolar cautery, which can damage the underlying sclera due to thermal conduction. The incision is continued on the level of the orbital septum and then directed to the frontozygomatic suture. The periosteum is incised and the fracture exposed (Fig. 3.**20**). After osteosynthesis the periosteum is approximated and the skin incision is closed using a running subcuticular or mattress suture. No subcutaneous closure is required.

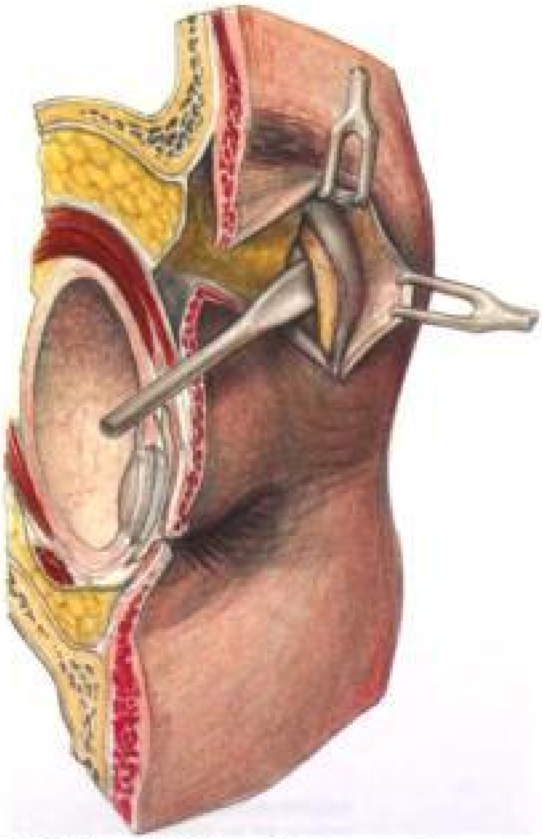


Fig. 3.**20** **Upper lid blepharoplasty approach**

Brow Approach

The brow incision for exposure of the frontozygomatic suture is the most common technique, with an extremely low complication rate. An incision is made through the skin parallel to the hair follicles at the superior border of the lateral brow overlying the frontozygomatic suture. The muscle fibers are divided by blunt dissection down to the periosteum. The periosteum is divided by sharp dissection. After osteosynthesis the periosteum is approximated and subcutaneous and skin sutures are performed. After surgery scars are sometimes visible and localized hair loss can occur.

Coronal Approach

The coronal approach provides excellent exposure of the cranium and upper craniofacial skeleton. Widening of the scar on the top of the head, paresthesias posterior to the incision, and weakness of the temporal branch of the facial nerve are common complications (Fig. 3.**21**). Shaving the head is not necessary if dural exposure is not required. The incision is made through the scalp, the subcutaneous tissue and the galea until the loose layer of the

Fig. 3.**21** **Cross-sectional anatomy of the temporal branch of the facial nerve.** Fusion of the temporal lines and position of the temporal branch of the facial nerve which passes over the zygomatic arch. (Giovanni Antonio Boltraffio, *Portrait of a lady as St. Lucy*, ca. 1500, Foundation Museum Thyssen Bornemisza, Madrid)

Fig. 3.**22** **Coronal approach**

scalp, between the galea and pericranium, is reached. Hemostasis can be obtained with cautery, scalp clips or running silk locking sutures. The dissection in the layer over the pericranium down to the supraorbital rim is relatively bloodless. Care must be taken below the fusion of the temporal lines because of the temporal branch of the facial nerve which passes over the zygomatic arch. The pericranium is incised 2 cm superior to the supraorbital rim and the dissection is continued over the bone to the supraorbital rim. When the neurovascular bundle of the frontal nerve is enclosed in a foramen, the bone bridge is excised (Fig. 3.**22**). To preserve the temporal branch of the facial nerve, the fusion of the temporal line and of the superficial and deep layers of the deep temporal fascia have to be identified (Fig. 3.**23**). If the dissection continues superficial to the fascia, the frontal branch of the facial nerve will be transected. Inferior to this line of fusion a fat pad is seen. An incision in the superficial layer of the deep temporal fascia exposes the fat. The dissection continues through the fat pad and leads to the zygomatic arch.

After incison a subperiosteal detachment on the superior border of the zygomatic arch is performed. The temporal branch of the facial nerve is now retracted laterally with the periosteum of the arch and the superficial layer of the deep temporal fascia (Fig. 3.**24**). To prevent facial nerve injuries never use sharp instruments since these may penetrate the nerve. Once the nerve has been protected the dissection can proceed in the subperiosteal layer to the lateral orbital rim. If the medial wall must be exposed, the anterior and the posterior limbus of the medial canthal ligaments and the lacrimal sac are identified. To avoid orbital hematoma the anterior ethmoid artery should be dissected carefully, clipped and divided.

Excessive traction over the eyes by the developed coronal flap can adversely affect the cardiac rhythm and may even cause a cardiac arrest.

If the canthal ligaments require reattachment they should be secured. Also the temporal fascia should be sutured to ensure proper soft tissue configuration. Wound closing can be obtained with staples or suture.

Surgical preferable approaches to the facial skeleton. After: Albrecht Dürer St. Apollonia 1521 Kupferstichkabinett, Berlin

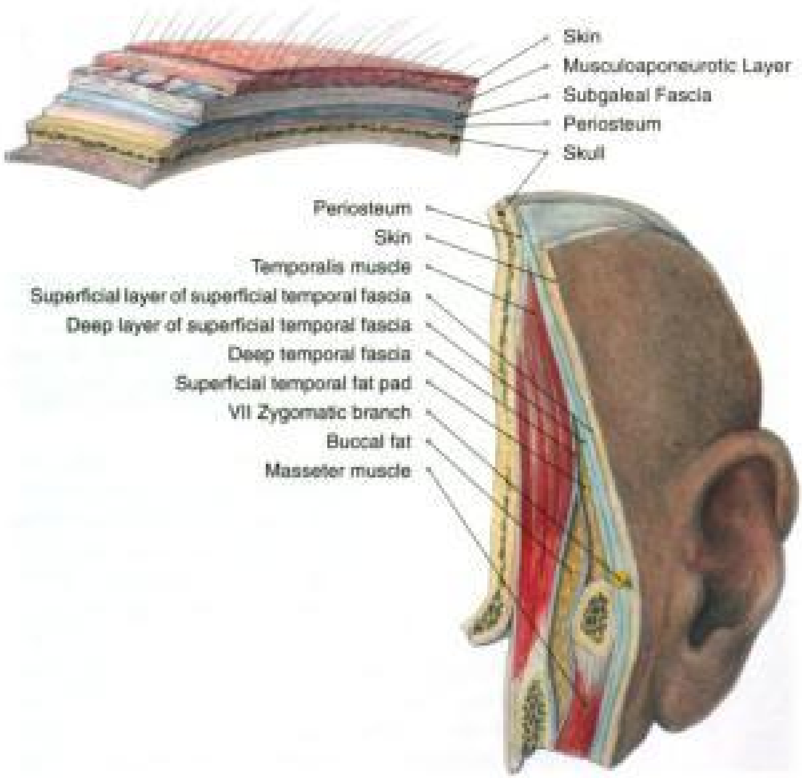


Fig. 3.23 **Cross-sectional anatomy of the zygomatic arch and the facial nerve**

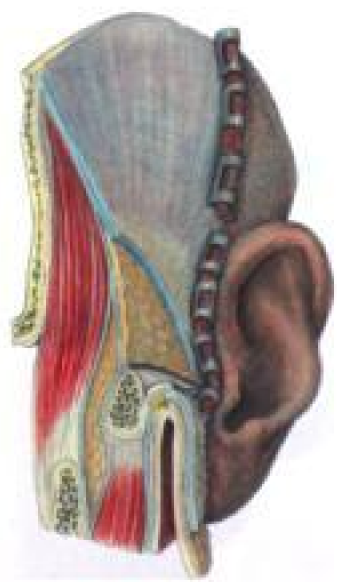


Fig. 3.24 **After incision on the superior border of the zygomatic arch the temporal branch of the facial nerve is retracted laterally with the periosteum of the arch and the superficial layer of the deep temporal fascia**

4 Materials and Instrumentation

Leen M. de Zeeuw

Introduction

The predominant aim of a manufacturer of osteosynthesis systems is to satisfy the aspirations of clinicians. Commercially available microplate and miniplate osteosynthesis systems exist in a variety of designs, materials, and mechanical properties (Aesculap, Howmedica, Leibinger, Lorenz, Martin, Medicon, Straumann, Synthes). It is up to the surgeon to choose between them. The Microplate and Champy Miniplate Osteosynthesis Systems, manufactured by Martin Medizin-Technik, are discussed here as general examples.

The Miniplate Osteosynthesis System was developed and modified by Champy and his coworkers (1975; 1976; 1977; 1978; Champy, 1983; 1986; Champy and Blez, 1992). Because this system is made to satisfy the philosophy and aims of Champy and his colleagues, the materials and instruments are manufactured to the highest standards.

Materials

Titanium and stainless steel are used in the manufacture of plates and screws of implant quality. To maintain consistently high levels of quality, all plates, screws, and instruments are subject to certificated international standards of control over both the raw materials and laboratory standards. Quality is further assured by highly automated production methods. These processes guarantee the metallurgical standards for the composition and microstructure, and the mechanical properties of the articles produced.

The Champy Miniplates Osteosynthesis System is available in two materials, titanium and stainless steel, both of implant standard. (Relevant standards are ASTM F 139/DIN 17443, ASTM F 67/DIN 17850, and ASTM F 136/DIN 17851).

Traditionally, stainless steel has been used widely as an implant material. Because of its greater biocompatibility and corrosion resistance, titanium has been substituted for it in maxillofacial surgery since the 1980s.

Mini Osteosynthesis Technique and Equipment

Miniplates

The miniplates are 2–9 cm long and 1 mm thick (Fig. 4.1). Miniplates are routinely used with 5 mm or 7 mm mini screws. A wide selection of pre-shaped miniplates is available to suit individual requirements.

Miniscrews

In general mini screws are monocortical and self-tapping. They are available in various lengths, including the head, of from 5–19 mm (Fig. 4.2). These screws are designed to be inserted at an angle of 30° to the plate surface and have a pitch of 1 mm, i.e. one turn of the screw penetrates the bone to a depth of 1 mm.

Fig. 4.1 **Four hole, 2 mm miniplate**

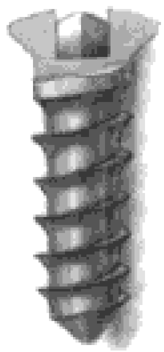


Fig. 4.2 **Miniscrew, 2 mm**

Mini Centre Drive® Screws

A variety of different screw heads are available for different systems (Fig. 5.3). To facilitate the osteosynthesis technique, the Centre Drive Mini Screw has been developed by Martin Medizin-Technik. The screw head is square in shape „ whereas the screwdriver is slightly conical. This combination assures a secure connection of screw and screwdriver device with improved intraoperative visibility (Fig. 4.3).

Recently these screws have been further improved and a Drill-Free Screw has been developed (see Chapter 22, Drill Free Screws).

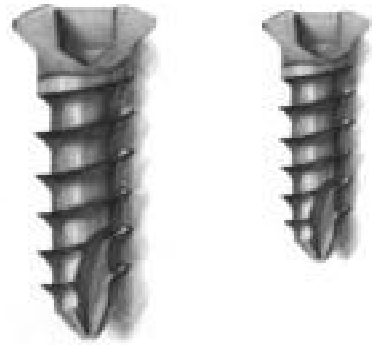


Fig. 4.3 **Centre Drive Screws, 2 mm and 1.5 mm**

Mini Drills

A successful osteosynthesis also depends on the quality of the holes drilled into the bone. Careful and accurate drilling is essential. For mini screws, drills of 1.6 mm in diameter are required to ensure firm anchorage for the self-tapping screws (Fig. 4.4).

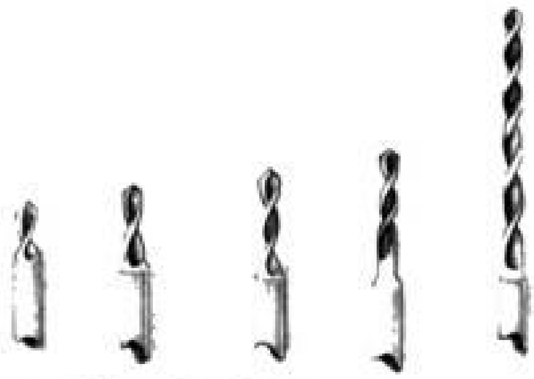


Fig. 4.4 **Drill bits with and without stops**

Mini-Instrumentation

The application of miniplates and screws requires a coordinated set of instruments, stored in a modular system, and combining the most frequently used osteosynthesis systems (1 mm, 1.5 mm, and 2 mm) in one set. The necessary instruments are shown in Figs. 4.5 and 4.6, including plate bending and modeling pliers, plate-holding forceps, depth gauge and a plate cutter. Screwdrivers are included for the 1.0, 1.5, and 2 mm screws. For the transbuccal approach a self-retaining retractor is included.

Fig. 4.5 **Modular osteosynthesis system (1 mm, 1.5 mm, 2 mm).** This shows the tray with screw tracks and color-coated plate cassettes

1.5 Micro Osteosynthesis Technique and Equipment

The principles of using miniplates has been extended into osteosynthesis for the midface and craniofacial areas. In these non load-bearing areas with thin bones, miniplates are excessively rigid and are also palpable through the thin skin in these areas. In accordance with basic principles of general orthopaedics, the aim should always be to reduce the volume and quantity of any implanted material. The micro osteosynthesis system achieves this goal.

In any situation where there is thin, lamellar bone structure and in those cases where there are no physiological or trauma-associated stresses, the use of the 1.5 mm micro osteosynthesis system is indicated.

1.5 mm Microplates

Microplates are much smaller than miniplates. They are 0.6 mm thick and 3.2 mm wide, permitting a good bone contour to be achieved (Fig. 4.7). A wide variety of different shapes is available, including straight, curved, L-, T-, and Y-shaped plates.

1.5 Micro Centre-Drive Screws

These screws are self-cutting and are available in lengths from 3.5–15 mm. Emergency screws are used when the 1.5 mm screws have been stripped in the bone. The Centre-Drive screw head design makes application of the microplates relatively easy. 1.5 Micro Centre-Drive Screws have the same shape and form as the 2 mm Mini Screws (see Fig. 4.3).

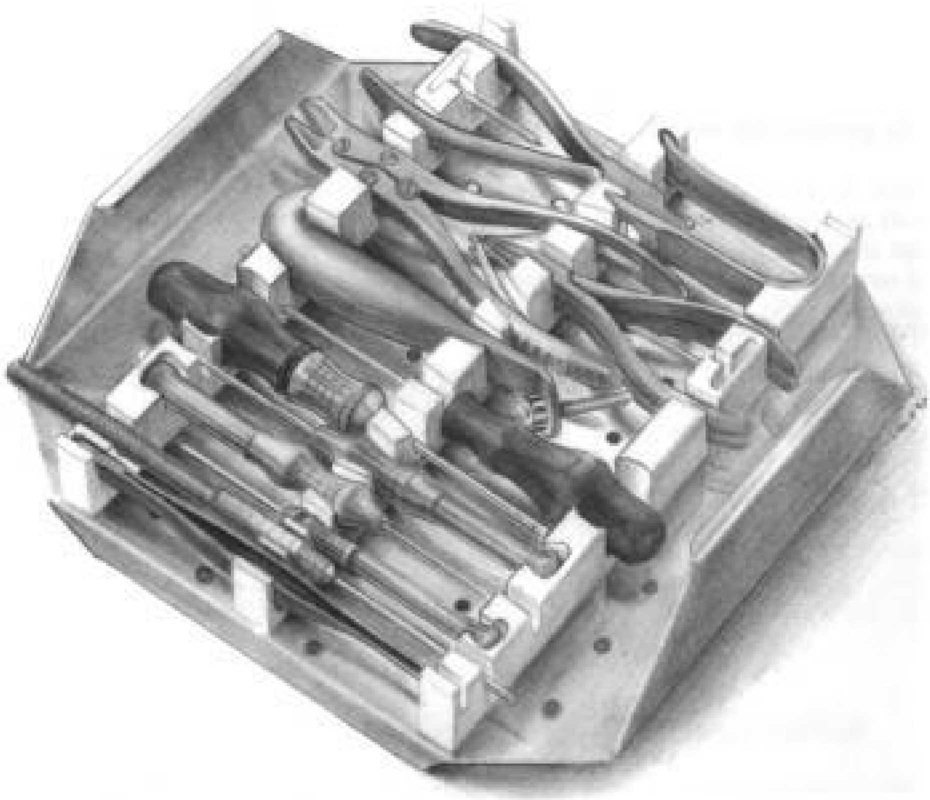


Fig. 4.6 **Sterilizing tray with instruments**

Fig. 4.7 **Four hole 1.5 mm microplate**

Micro Drills

For the 1.5 mm system, drills of 1.1 mm diameter are required, this being the core diameter of these screws.

Micro-Instrumentation

A modular system of miniaturized instruments, such as bending and modeling pliers, plate-holding forceps, depth gauge, plate cutter as well as screwdrivers, has been developed to fit the special requirements of the micro osteosynthesis technique.

The Modular Osteosynthesis System

A multiple osteosynthesis system has been developed to meet the requirements of osteosynthesis techniques for the craniomaxillofacial skeleton and integrating the 1 mm and 1.5 mm micro systems and the 2.0 Champy Mini System into one integrated system (see Fig. 4.5). This system functionally addresses the following osteosynthesis indications:

- guided tissue regeneration;
- implantology;
- preprosthetic reconstructive surgery;
- orthognathic surgery;
- craniofacial surgery;
- craniomaxillofacial trauma;
- reconstructive surgery;
- skull base surgery.

Most other indications can be covered with this set.

5 Mandibular Fractures including Atrophied Mandible

Hans-Dieter Pape, Klaus Louis Gerlach and Maxime Champy

Introduction

The experimental and clinical investigations of Champy *et al.* (1976a, 1976b, 1977) established the biomechanical preconditions and the surgical basis for successful miniplate osteosynthesis. The most important result of Champy's investigations was the determination of an ideal osteosynthesis line in the biomechanically favorable region at the base of the alveolar process. The strength of the plate and the diameter of the monocortical screws were adapted to the biomechanical demands of the mandible. Using these results many companies developed osteosynthesis systems. The use of miniplate osteosynthesis in fractures of the horizontal mandible has become a generally accepted procedure. Nevertheless the mechanical characteristics of the miniplate systems produced by different firms can vary widely.

Fig. 5.1 **Manual repositioning of the fracture parts**

Technique

The technical procedure is the same for all fractures of the mandible; the following points should be observed.

Time of Treatment

The treatment of all mandibular fractures should take place, if at all possible, during the first 12 hours after the accident (Champy and Lodde, 1976). There are various reasons for this recommendation, in particular the relationship between delayed treatment and increase in the rate of infection (Gerlach and Pape, 1988).

Anesthesia

Most mandibular fractures require intubation anesthesia. Our own experience showed that miniplate osteosynthesis under local anesthesia with premedication is both possible and saves staff time. The main indication for the use of local anesthesia is a simple or double fracture in the front part of the mandible or in the area of the wisdom teeth. Local anesthesia may also be favored in patients who have a poor general medical condition prejudicial to intubation anesthesia. Approximately 40% of patients can be operated on using local anesthesia (Walz *et al.*, 1996).

Reestablishment of occlusion

The feasibility of manually repositioning dislocated mandible fragments should be checked. If correct occlusion to the upper jaw can be achieved without difficulty, intermaxillary fixation is not required. However, where problems arise, for instance in multiple fractures, preoperative splinting and intermaxillary fixation is necessary. With the help of a capable assistant, the experienced surgeon should be able to reposition many simple fractures manually (Fig. 5.**1**). An inexperienced surgeon, however, should certainly start with splinting of the upper and lower jaw by the eyelet method of intermaxillary fixation (Ivy, 1922; Obwegeser, 1952; Stout, 1942). Remember that each fractured fragment should be fixed individually to the upper jaw. A splint bridging the fracture makes correct occlusal reduction impossible.

Gingiva Incision

To avoid dehiscences the rules for incisions, as described in Chapter 3 Surgical Approaches, must be observed. The incision line should be 5 mm below the level of the attached gingiva (Champy and Lodde, 1976). Occasionally a marginal rim incision is indicated. The length of the incision must allow free access to the fracture line and the surrounding area. If two plates are to be applied in the front area an extension of the incision is necessary.

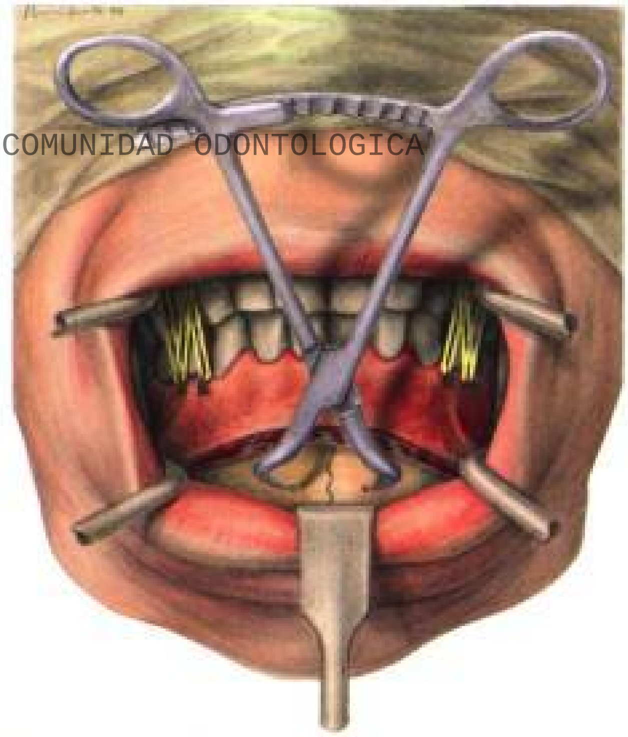


Fig. 5.2 **Fractured jaw.** Fixation with a bone clamp and intermaxillary fixation. (For details of treatment see Figs. 5.**15**, 5.**16**)

Miniplate Choice

The normal four-hole plate with 5–7 mm screws is preferred in most cases. Alternatively, four-hole plates with bar or six-hole plates with or without bar may be indicated for anatomical reasons. (For example, where there is involvement of the foramen mentale, danger of injury to root tips, or there are comminuted fractures).

Miniplate Osteosynthesis

After exposing the fracture line, the fragments are reduced manually. In difficult cases, a bone hook may be applied to the proximal fragment and countertraction applied simultaneously to the anterior fragment, to facilitate reduction and interdigitation of the fracture ends. The use of bone clamps for the temporary immobilization of fragments simplifies the adaptation and fixation of a miniplate (Fig. 5.**2**). Following reduction, the occlusion is checked and secured by hand adaptation or through simple intermaxillary wiring. With modeling pliers and modeling lever, the osteosynthesis plate has to be precisely adapted to the outer cortical surface at the level of the osteosynthesis line. After drilling a hole, the screw is inserted and only then is the next hole drilled. After the plate has been fixed with two screws on one side of the fracture, care has to be taken before drilling the first hole in the other fragment, so that an optimal adaptation of the fragments can be achieved. Every plate must be fixed with at least two screws in each fragment. Once one or more screws have been inserted, no attempts should be made to improve the adaptation of the plate, since this would result in the loosening of screws already inserted. Instead, the plate should be removed and adapted correctly. If a screw fails to gain a secure grip close to the fracture line, the position of the plate should be altered; alternatively a plate with bar can be used (Fig. 5.**3**). In comminuted fractures or where there are detached triangular pieces of bone, longer plates with six or more screws should be used (see Fig. 5.**20**). The drill should if possible be held perpendicular to the bony surface (Fig. 5.**4**). An angulation up to 30° is allowed (Champy and Lodde, 1976), but it must be strictly monoaxial. Any change in the drilling angle during the drilling procedure results in a conical drill hole that fails to guarantee a firm grip on the screws (Fig. 5.**5**). The normal thickness of the cortical layer is 3 mm, and since the screw threads lie about 1 mm apart, screw fixation depends on three screw threads. A conical drill hole might reduce the grip of the screw to one or two threads. Excessive tightening of the screw produces microfractures within the drill hole (Fig. 5.**6**). When the osteosynthesis has been completed, stability and occlusion should be checked with the lower jaw in motion. After replacing the loosened soft tissue, the mucosa should be sutured, together with the periosteum.

To avoid a hematoma, the soft tissue of the chin should be stabilized against the chin bone with an extraoral tape dressing (Fig. 5.**7**). For the same reason, a Redon vacuum drainage or a simple piece of tubing should be used for drainage in the premolar and molar region. Postoperative intermaxillary fixation is not required. If intraoperative splinting has been carried out, this fixation can remain in place for some days. It may be helpful where the patient has difficulty in finding the correct occlusion. Immobilization also encourages soft tissue wound healing (Khoury and Champy, 1987).

Fig. 5.3 **Fractured jaw.** Reposition and fixation by two four-hole plates

Fig. 5.4 **Drill position**

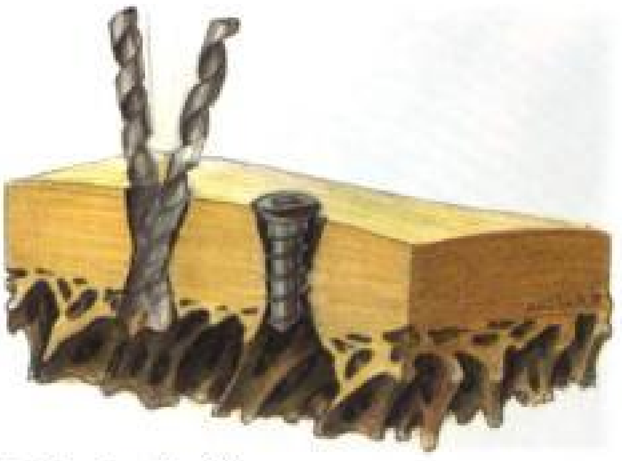


Fig. 5.5 **Excentric drill**

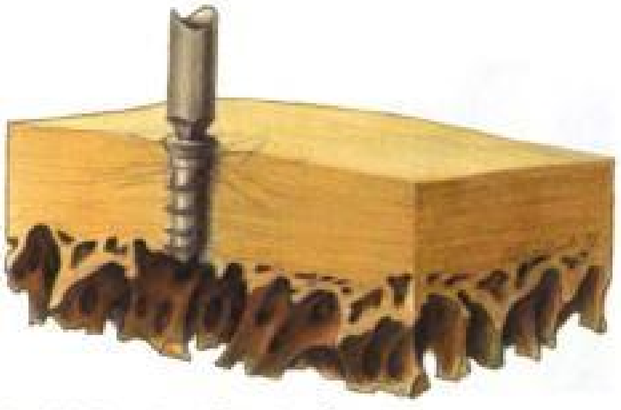


Fig. 5.6 **Excessive tightening of a screw**

Fig. 5.7 **Extraoral plaster dressing.** (after Albrecht Dürer, *St. Apollonia*, 1521. Kupferstichkabinett, Berlin)

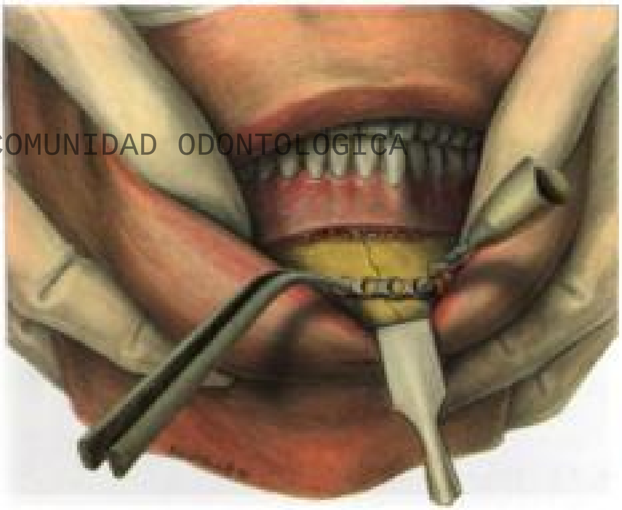


Fig. 5.8 **Fracture in the symphysis region.** Fixation of the lower plate first

Fig. 5.9 **Four-hole plate with bar for preservation the apex of the canine**

Different Areas Require Special Measures

The Interforaminal Area

To neutralize torsion forces in the symphysis region between the mental foramina, two parallel plates should be used (Sustrac and Villebrun, 1976). The gap between them should be 4–10 mm. It is recommended that the lower plate be fixed first and then the subapical plate. Insertion of the screws should always follow the same sequence; first hole, first screw then second hole, second screw, on one fragment (Fig. 5.**8**).

The Canine and Premolar Area

Fractures behind the mental foramen can be sufficiently stabilized by only one plate. In this area there are two anatomical danger points. The apex of the canine is normally long and may lie close to the osteosynthesis line. Therefore it is necessary to make sure that the drill holes are placed beside the apex and do not damage them. If this is not possible with a simple four-hole plate, a four-hole plate with bar should be used (Fig. 5.**9**). In most cases this allows the correct positioning of the drill holes. The nervus mentalis lies below the osteosynthesis line. It emerges from the mandible between the apices of the two premolars through the foramen mentale. If care is not taken, the mental nerve may be damaged by the application of the plate. It is therefore advantageous to place the concave section of the plate between the screw holes exactly over the exit point of the nerve (Fig. 5.**10**) or to bend the plate in an edgewise direction over the exit point. With a fracture situated at the mental foramen a second plate below the nervus mentalis can be necessary if some torsional instability is detected on checking the osteosynthesis.

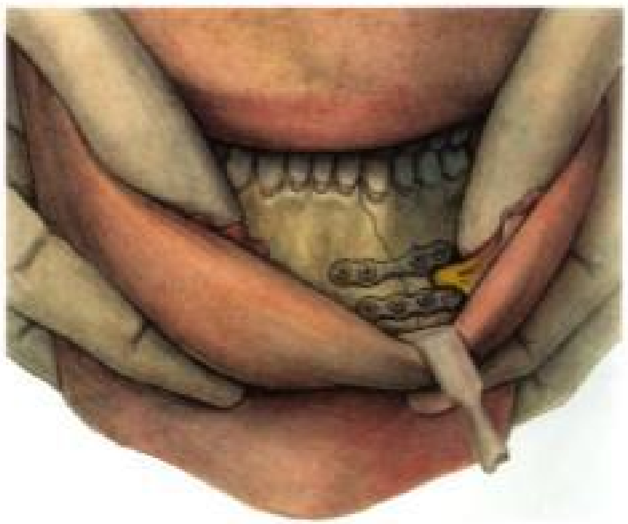


Fig. 5.10 **Plate fixation over the foramen mentale.** Surgical approach by means of marginal rim incision

The Molar Area and the Angle of the Mandible

If the mouth is small and the intraoral application of a drill and screwdriver becomes too difficult, either an angled screwdriver or the transbuccal approach can be used. After puncturing the soft tissue of the cheek, transbuccal instruments will facilitate the use of the drill and avoid injury to the cheek (Fig. 5.**11**).

In a fracture of the angle of the mandible, the plate should be located on the proximal fragment medial to the oblique line, so that it is bent over the surface and the proximal screws are placed in a nearly sagittal direction. The two screws in the distal fragment can then be fixed in a more horizontal direction (Figs. 5.**12**, 5.**13**). In certain

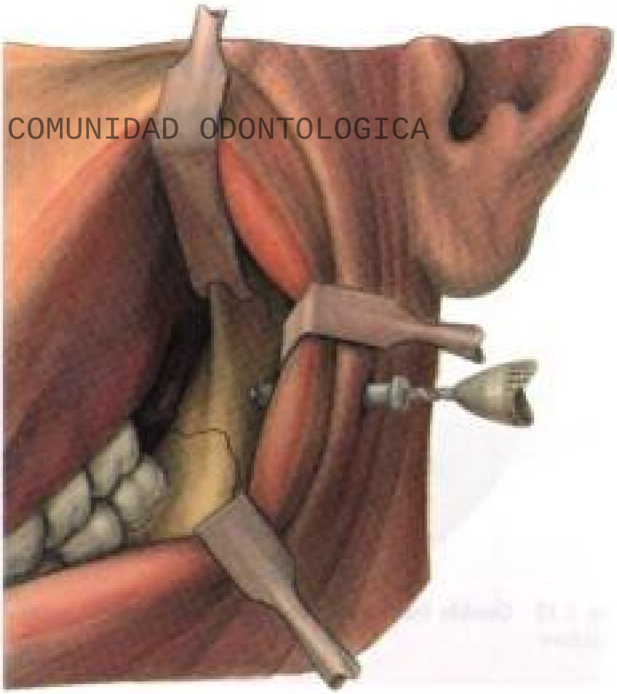


Fig. 5.**11** **Transbuccal approach with instruments**

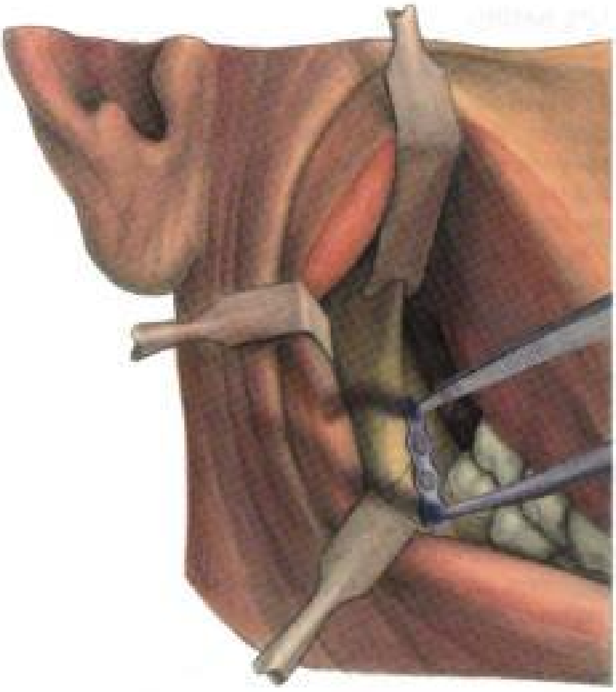


Fig. 5.**12** **Plate fixation at the angle of the mandible.** Control of the position

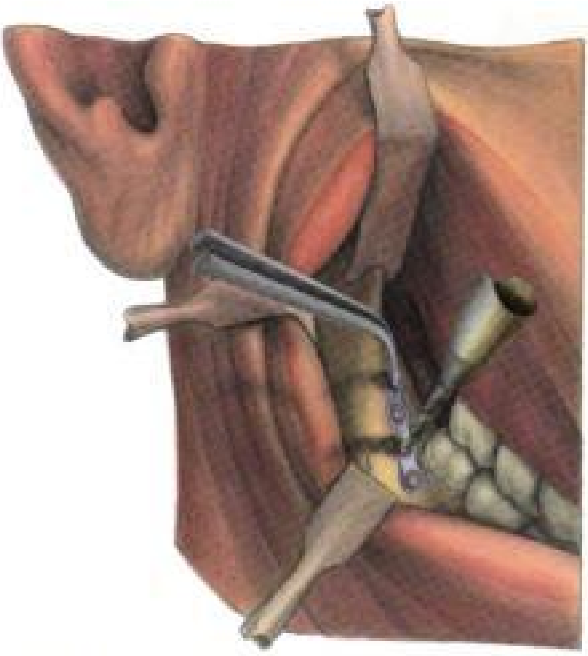


Fig. 5.**13** **Plate fixation at the angle of the mandible.** Drilling of the first hole

Fig. 5.**14** **Plate fixation at the outer surface of the mandible**

cases—with simultaneous fractures of the alveolar process or when an impacted wisdom tooth is present—the plate may be fixed to the outer surface of the mandible, corresponding in position to the course of the tension line (Fig. 5.**14**).

The Ramus

Intraoral miniplate osteosynthesis can be recommended for use in fractures of the lower section of the ramus ascendens. For fractures below the incisura mandibula, adequate visual control of the intraorally-applied plates and the correct insertion of the drill and screwdriver are possible.

In cases of fractures of the condylar neck of the mandible, lag screw or lag screw plate osteosynthesis with extraoral approach, or extraoral and intraoral miniplate osteosynthesis as described in Chapters 9–13 should be considered.

Multiple Fractures

When there are two or more fractures of the mandibular body, the fracture lines are exposed first. Thereafter the fragments are reduced and held firmly in occlusion with intermaxillary wiring during the operation. The osteosynthesis is performed first in the tooth-bearing section of the jaw (Champy and Lodde, 1976). For example, in cases of fractures at both the midline and angle of the jaw, the midline fracture would be treated first. In this way it is easier to avoid malocclusion (Figs. 5.**15**, 5.**16**).

Fig. 5.**15** **Double fracture—first step.** Fixation of the midline fracture

Fig. 5.**16** **Double fracture—second step.** Fixation of the angle fracture

Medicinal Therapy

A preoperative antibiotic medication is recommended on the day of the operation, either as one-shot medication 1 hour before surgery or three doses distributed over the operation day. Anti-edematous drugs are usually not prescribed. If the soft tissue is severely traumatized, intraoperative medication with 250 mg cortisone may be given and, to minimize hemorrhage, local anesthesia with adrenaline is recommended.

Postoperative Care

The patient is given soft food for about 7 days, following which the improving muscle activity allows a slow increase of chewing pressure. An oral hygiene regime must be observed. The sutures can be removed after 7–10 days. The miniplates should be removed under local anesthesia, usually after 2–4 months.

Special Fracture Situations

The particular anatomic conditions of a child's jaw, of the edentulous atrophied mandible of elderly patients, and of patients with comminuted jaw fractures or bone defects all call for changes in the normal miniplate treatment.

Fig. 5.17 **Child up to 6 years.** Jaw fracture in the molar region, stabilized by a microplate

Fig. 5.18 **Child 6–12 years.** Jaw fracture in the front region, stabilized by one microplate

Mandible Fractures in Children

Fractures in children up to 6 years of age normally receive conservative treatment. An indication for osteosynthesis may be a simple or multiple fracture with displacement, especially when the possibilities of conservative fixation are limited. In such cases two changes from the usual procedure should be made; a single microplate (1.5 mm system) is normally sufficient for the stabilization of a fracture, and because of the position of the teeth germs, the microplate should always be placed at the lower border of the buccal side (Fig. 5.17). Fractures of the jaw in children from 6–13 years also require that attention be paid to the position of the teeth germs, particularly in the lateral side of the mandible. If the indication for osteosynthesis is given by dislocation or instability, a normal miniplate should be used. It should, however, as with younger children, also be placed at the lower border. The reduced chewing force in children and the much quicker healing of the bones make this shift from the tension line to the lower border possible, as pointed out by Champy and Lodde 1976 (Fig. 5.18). Young people between the ages of 12 and 18 can be treated in the same way as adults—the plates are applied to the osteosynthesis line.

The Edentulous Atrophied Mandible

If the bone form is normal, fractures of edentulous mandible are treated according to the same principles as mandibles with teeth. However, if an advanced atrophy of the mandible (<10 mm) is evident, the tension zone shifts down towards the lower border, and the miniplate must be placed accordingly. Thus in cases of advanced atrophy the screws may endanger the nervus alveolaris inferior, particularly in the premolar region. Since the cortical bone on the occlusal side is normally thin, the miniplate may have to be fixated very close to the lower border (Fig. 5.**19**). With these patients, bone is brittle and does not provide a solid grip for the screws. The use of a six-hole plate and fixation with three screws on each fragment can be recommended. As the chewing forces are reduced in edentulous atrophied jaws there is no danger to the stability of the osteosynthesis. In cases of extreme atrophy the soft tissue is removed without the periosteum and the miniplate is fixed extraperiosteally. In this way a further reduction of blood supply to the bone can be avoided. In cases of severe atrophy, the miniplate is the most suitable osteosynthesis material; wire does not provide sufficient stability and fixation, and larger plates can lead to an even greater atrophy.

Fig. 5.**19** **Fracture of an edentulous mandible with advanced atrophy.** Plate fixation

Defect and Comminuted Fractures

Where a bone fragment at the lower border is missing, the self-stabilization of the compression zone cannot function. It is therefore necessary to use two plates. One is placed in the tension zone above the missing fragment; the second plate is placed lower to bridge the defect and to stabilize the bone (Fig. 5.**20**).

Two miniplates also need to be used in comminuted fractures because multiple fragments cannot be stabilized with one plate (Fig. 5.**21**).

Fig. 5.**20** **Defect fracture with two plates in position**

Fig. 5.**21** **Comminuted fractures with two plates in position**

Teeth in the Fracture Line

The indications for extracting teeth along the fracture line, as well as the prognosis for such teeth as are retained, have been the subject of many papers. Removal of teeth along the fracture line is recommended when there is apical or marked periodontal bone loss, or when there is any sign of infection, or when teeth have been badly damaged by caries or trauma. It is also recommended that impacted wisdom teeth be removed from the fracture line, unless they can be utilized for the fixation of small-plate osteosynthesis, or their removal would cause a loss of bone from the fracture margins. In the former circumstances, the wisdom tooth should be removed together with the osteosynthesis material in a second procedure under local anaesthetic 3 months after fracture reduction.

Applying these criteria, 18 (23%) of 78 'fracture line' teeth were extracted as a primary measure in the cases reported on by Berg and Pape (1992). Only one of the teeth retained subsequently required extraction, so that 98% of these retained teeth were successfully salvaged. This result is comparable to that of Günther, Gundlach, and Schwipper (1983), but it is in contrast to those of Ewers, Reuter, and Stoll (1976), who subsequently extracted 14% of retained fracture line teeth, and Stoll, Niederdellmann, and Sauter (1983), who later extracted 20% of retained teeth.

Berg and Pape's findings (1992) showed that a higher proportion, 22%, of fracture line teeth became non vital. Similar findings have been published by other researchers.

The periodontal condition of teeth retained in the fracture line is another consideration. There is no obvious reason why such teeth should show an increase in gingival pocket depth after postoperative healing is complete. Berg and Pape (1992) observed in their sample that 88% of the patients had no increase in pocket depth around such teeth when compared with the corresponding contralateral tooth. Hoffmeister (1985), Günther, Gundlach, and Schwipper (1983), and also other authors found no significant differences in similar studies.

Moreover, Hoffmeister (1985) reported that the horizontal mobility of retained fracture line teeth, once healing is complete, does not appear to differ from the normal physiological range for healthy teeth. Schmitz, Höltje, and Cordes (1973) and Krenkel and Grunert (1987) published similar results. No periapical osteitis was reported by Berg and Pape (1992), Günther, Gundlach, and Schwipper (1983) and Schönberger (1956). However, Schmitz, Höltje, and Cordes (1973) and Fuhr and Setz (1963) reported periapical osteitis in 11% and 11.7%, respectively, of the teeth in their studies.

In conclusion, the good prognosis for retained teeth makes clear that fracture line teeth should only be extracted when a definite indication exists.

6 Hooks for Intermaxillary Immobilization

Hendrik Terheyden

Introduction

Intermaxillary fixation is usually accomplished utilizing either interdental wiring or arch bars. This technique, however, is not possible in those patients who are either edentulous or have severe hypodontia.

Immobilization by Wiring

Immobilization can also be obtained utilizing circumzygomatic or piriform aperture suspension wires in combination with circumferential mandibular wiring to immobilize a mandibular fracture. Usually this method requires general anesthesia (Krüger, 1964).

Immobilization using Hooks

Dal Pont (1965) described a less invasive method of achieving intermaxillary fixation with hooks that engaged the inferior mandibular border and the piriform aperture. The disadvantage of hooks is their tendency to dislocate.

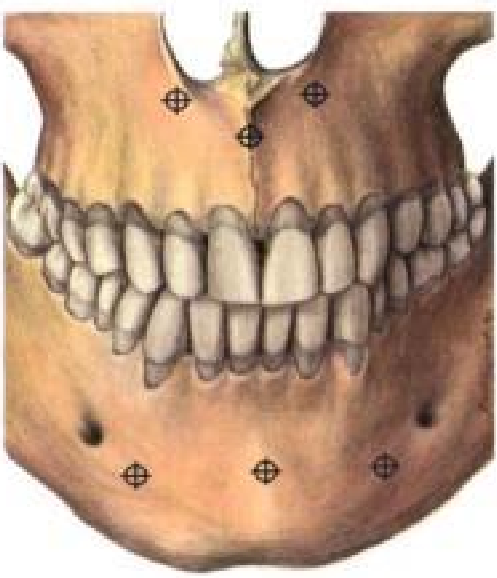


Fig. 6.1 **Preferred sites for placement of miniscrew hooks**

Miniscrew Hooks

An elegant alternative is the insertion of mini screw hooks. They are inserted subapically and bicortically into the anterior mandible and into the anterior maxilla below the nasal spine. The procedure, originally described by Otten (1981), can be performed under local anesthesia. The regions can be exposed by small vertical incisions in the median labial frenulum. If more fixation is required, additional mini screw hooks can be used laterally as well. With a 12 mm mini screw, hand-bent hooks of 1 mm steel wire can be secured (Car *et al.*, 1986; Shetty and Niederdellmann, 1987; Ito *et al.*, 1988; Toth-Bagi, Ujpal, and Gyenes, 1994). A second intervention under local anesthesia is required to remove the devices (Fig. 6.**1**).

Mini screw hooks can be applied in children, after eruption of the central incisors, and in atrophic jaws in aged patients. Mini screw hooks can be utilized in the edentulous patient and in the dentate patient as well. The insertion of an acrylic splint helps to stabilize the dentition and prevent unwanted tooth migration. In the edentulous patient dentures should be worn to maintain the vertical dimension (Fig. 6.**2**). If no dentures or splints are available then long transmucosal miniplates can be placed in the midline (Reuter and Koper, 1985; Wolfe, Lovaas, and McCafferty, 1989) or bilaterally (Hori *et al.*, 1992) from the nasal aperture to the anterior mandible to achieve intermaxillary immobilization (Fig. 6.**3**).

Ligatures

Transmucosal osteosynthesis screws also provide abutments for intermaxillary ligatures or elastic bands. Screws of different diameters have been recommended; 2 mm mini screws (Arthur and Berardo, 1989; Onishi and Maruyama, 1996; Jensen, 1997); 2.7 mm diameter screws (Busch and Prunes, 1991; Busch, 1994; Isaacs and Sykes, 1995); 3.5 mm diameter screws (Win *et al.*, 1991). A special transalveolar 2 mm screw with a capstan head was reported by Jones (1997).

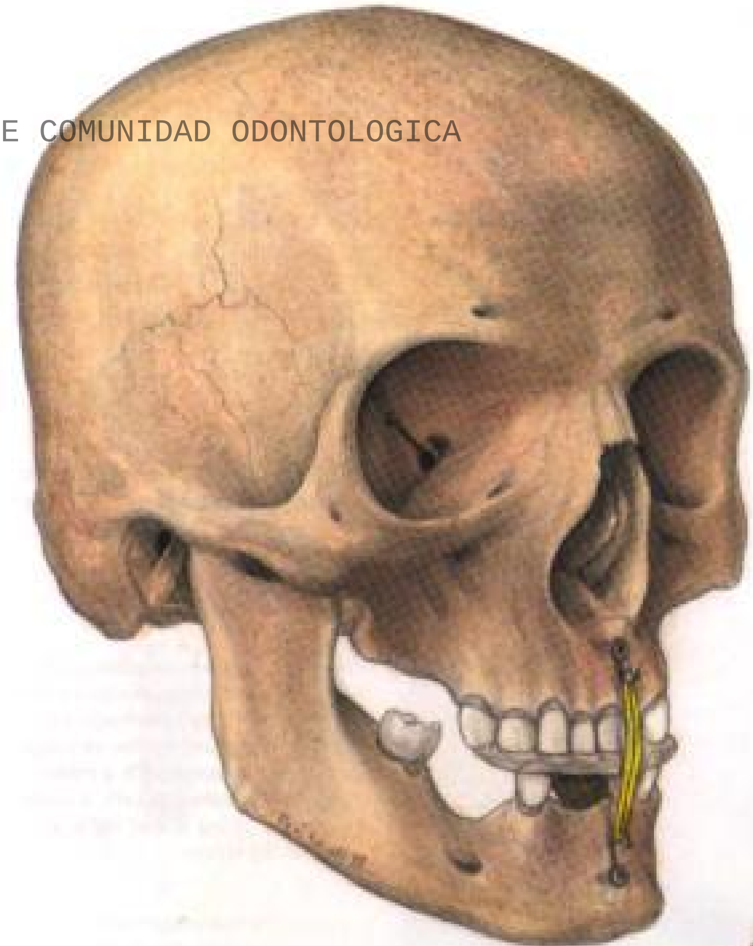


Fig. 6.2 **Conservative treatment of a condylar fracture in a nearly edentulous patient.** An intermaxillary acrylic splint is used to reinforce the remaining teeth for maintenance of the vertical dimension and to prevent a median diastema between the upper incisors, caused by the elastic bands

Fig. 6.3 **Intermaxillary immobilization of edentulous mandible by transmucosal miniplate**

7 Principles of Application of Lag Screws

Franz Härle

Introduction

Lag screw osteosynthesis is a form of osteosynthesis in which absolute interfragmentary stability is generated by screws which transfix the fracture gap. The screw is under tension. The screw holes are prepared in such a way that when a screw is tightened, it engages the bone only in the distal fragment – not in the fragment adjacent to the screw head. With a minimum of hardware the lag screw produces interfragmentary stability directly in the center of the fracture line (Fig. 7.1). In contrast, plates apply stability indirectly from the external cortex by tension bending (see Fig. 2.2). The function of a lag screw provides mechanical rest and stability. Therefore lag screws facilitate direct bone healing (Müller *et al.*, 1991).

Toulouse Lag Screw

The Toulouse mini lag screw is a further development within the Champy Titanium Mini Osteosynthesis System (Boutault *et al.*, 1987, 1989). The same instruments and drills may be used for insertion (Fig. 7.2).

Fig. 7.1 **Lag screw osteosynthesis duces interfragmentary rest and stability by interfragmentary friction due to the serration of the fragments with a minimum of hardware.** Left, a cortical screw as lag screw; right, a typical lag screw

Fig. 7.2 **Preparation of a Toulouse mini lag screw in mandibular fracture.** (A) Toulouse lag screw applied to a lamellar fracture of the outer cortex. (B) Modified towel clip holds the bone fragments in reduction. (C) Bicortical drilling at the internal or core diameter of the screw. (D) Depth gauging. (E) Insertion of a screw resulting in compression of fracture by bicortical application

Cortical Lag Screw

To understand the concept of a lag screw it is necessary to understand the basic design of the cortical screw which is the predominant type of screw used in the maxillofacial region (Fig. 7.**3**). Each cortical screw consists of a head and a shank; the entire length of the shank has threads and defines the screw length. Screw heads come with a variety of configurations; the popular ones have either a straight, a cruciform, a hexagonal or a square slot (Fig. 7.**4**). The shank has an internal diameter, also known as core diameter, and an external diameter or thread diameter. The cortical screw can act as a lag screw only when the hole in the fragment adjacent to the screw head is over enlarged. This is called the gliding hole. The diameter of the gliding hole is equal to or greater than the thread diameter of the screw. The diameter of the screw hole in the distal fragment is smaller than the gliding hole and corresponds to the core diameter of the screw. The hole in the distal fragment is called the traction hole (Fig. 7.**5**).

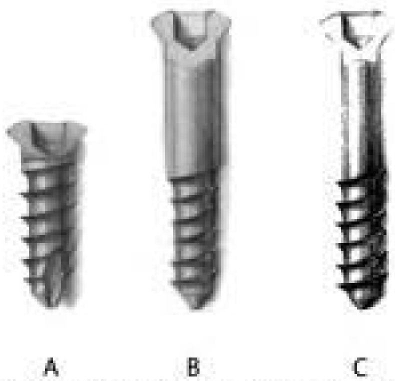


Fig. 7.**3** **Configuration of screws.** (A) A cortical screw with a head and a shank. The entire length of the shank has threads and defines the screw length. The shank has an internal diameter, known as the core diameter, and an external or thread diameter. (B) A lag screw Only the distal part of the screw has threads of the same diameter as the shank in the central part of the screw. (C) A special lag screw at right (Toulouse mini lag screw). Only the distal part of the screw has threads. The diameter of the shank in all parts of the screw is the same

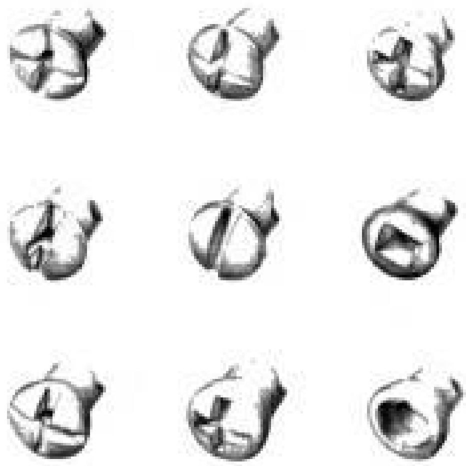


Fig. 7.**4** **Screw heads with a variety of configurations from different systems and companies.** Top, cruciate and Phillips screw heads. Center, slotted and center drive screw heads. Bottom, special screw heads with cruciate, Phillips, and hexagonal socket heads

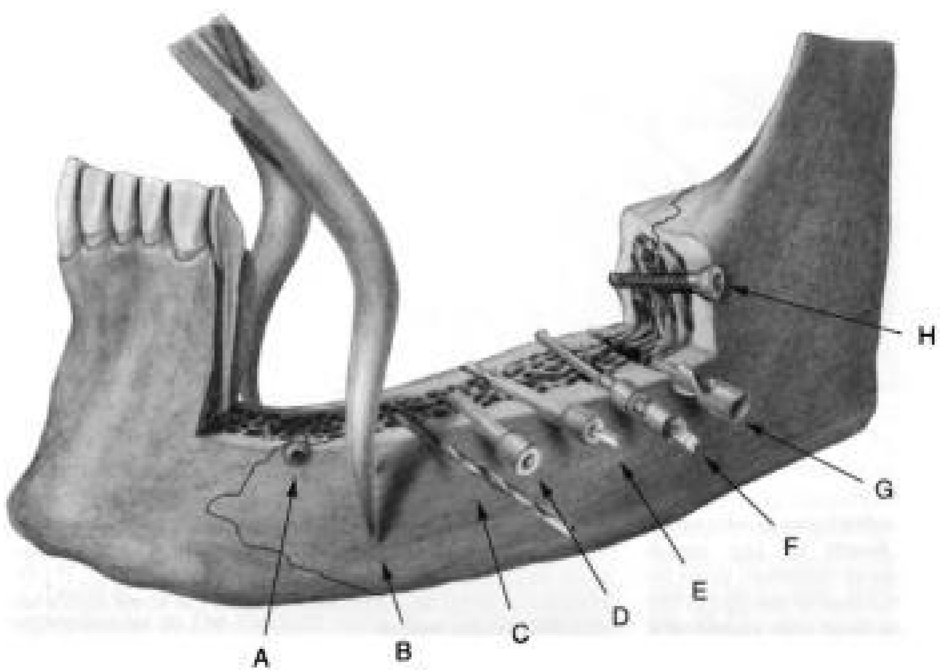


Fig. 7.**5** **Preparation of lag screws in mandibular fracture.** (A) Lag screw applied to a lamellar fracture of the outer cortex. (B) Modified towel clip type of bone holding forceps may be used to hold the bone fragments in reduction. (C) Drilling of gliding hole in near cortex. (D) Insertion of centering guide in the gliding hole. (E) Use of centering guide to drill traction hole coaxially. (F) Depth gauging. (G) Inlet countersinking near cortex. With non self-tapping lag screws, tapping of traction hole is necessary. (H) Insertion of screw resulting in compression of fracture by bicortical application

True Lag Screw

In contrast, a true lag screw has threads only on its terminal end. When used the threads engage the distant cortex and the head seats against the proximal cortex, resulting in compression and mechanical rest (Fig. 7.6).

A depression or countersink corresponding to the screw head is created at the opening of the gliding hole. Screws with a spherical head provide an area of extensive surface contact of the screw head with the bone, thus avoiding stress concentration and micro fractures. Conical heads or screws with a washer used without countersink produce a random, circular bone contact. Circular bone contact by concave screws or spherical screws with biconcave washers (Krenkel, 1994) can produce stress concentration and local overload. This can result in a fracture of the cortical bone when tightening the lag screw and incomplete failure of the osteosynthesis. All those lag screws that are conical, conical with washers, spherical, spherical with biconcave countersink washers or of concave head design can crack the thin

Fig. 7.6 **Configuration of different types of lag screws and washers.** (A) Monocortical lag screw with self adapting spheric washer. (B) Bicortical lag screw with self adapting spheric washer. (C) Bicortical lag screw with threads only in the distal part of the screw. (D) Bicortical lag screw with threads in the entire length. (E) Bicortical lag screw with a washer and threads in the entire length. (F) Bicortical lag screw with a biconcave washer. (G) Bicortical lag screw with a conical head. (H) Bicortical lag screw with a spherical head

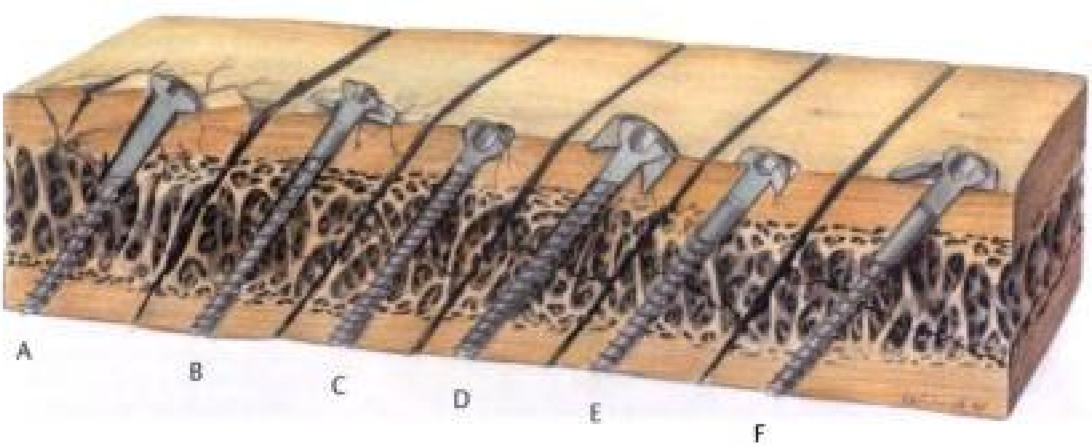


Fig. 7.7 **Stress concentration and microfractures produced by application of different screw heads in lag screw osteosynthesis.** (A) Conical head produces maximum stress on the bone surface. (B) Conical head with a washer distributes the stress to the bone. (C) Spherical screw head with countersink puts less stress on the bone. (D) Spherical screw with biconcave washer puts even less stress on the bone. (E) Concave-shaped screw head shows a similar stress distribution effect. (F) Distribution of stress by application of spherical screw with a self-adapting spheric washer

Fig. 7.8 **Self-adapting spheric washer**

cortex of craniofacial bones. Problems of transfer of load between the screw head and the bone are even more severe when the screw is inserted at an angle (Fig. 7.7). To prevent any fragmentation of bone by lag screw application a technique has been developed that includes a self-adapting spheric washer (Terheyden, 1998). The spheric washer has a spheric hole on top, which corresponds to the spheric shape of the screw head. At the bottom it has an excentric slot, so that the washer automatically aligns its position with the cortical surface at any angle of the screw. In combination the screw and washer act like a spherical articulation. Countersinking of the bone is not necessary, thereby avoiding weakening it (Fig. 7.8).

The screws for maxillofacial applications must be remarkably strong and provide stability for early postoperative mobilization. Rotational forces on the fragments can be neutralized by the use of two or more lag screws. However, under compression there is a high interfragmentary friction because of the serrated surfaces of the fragments. In anatomic reduction, this may allow the use of a single lag screw in certain indications.

To avoid shearing forces on the fragments in mandibular fractures, the holes for lag screws should be drilled perpendicular to the fracture plane. It must be emphasized that the use of lag screws demands technical precision; however, limited exposure of the operative field often makes it difficult to evaluate their placement. In some situations it may be necessary to perform a transcutaneous stab incision.

Position Screw

A lag screw effect can be achieved only if the screw can pass freely through the gliding hole and engage the cortex in the opposite fragment. If the diameter of the gliding hole is smaller than the thread diameter of the screw, the screw will engage bone in the gliding hole. In this situation, similar to that of two nuts on the same bolt, the fracture gap will remain open without any interfragmentary compression. There are certain clinical situations where this transfixation effect is desired. In such cases the screw is referred to as a 'position screw.' The position screw, using threaded holes in both cortices, finds application in orthognathic procedures, such as sagittal split-ramus osteotomies, where it helps to maintain spatial relationships and the position of the condyles (see Fig. 19.7).

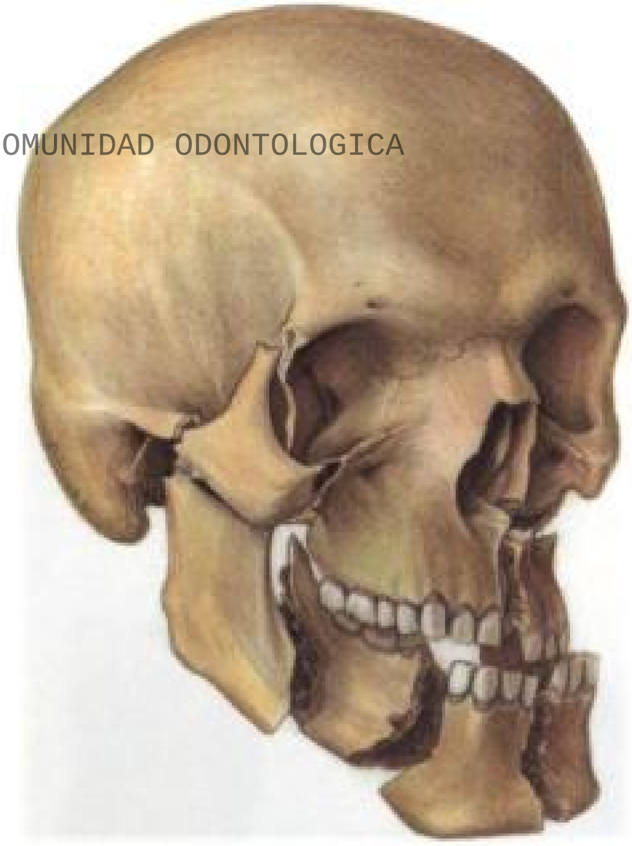


Fig. 7.9 **Maxillofacial fractures**

Fig. 7.10 **Application of lag screws at maxillofacial fractures**

Indications for Lag Screw Osteosynthesis

Lag screws have numerous applications in the mandible, but they have limited use in the midface region. With the exception of oblique fractures in the periorbital or subnasal regions, which can be reduced by lag screws, the bone elsewhere in the midface is too thin to permit placement of screws (Figs. 7.**9**, 7.**10**).

Simple fixation with lag screws is ideal for wide sagittal fractures or for lamellar fractures that have a large area of interfragmentary contact and sufficient friction between the lamellae. If two or even three lag screws are used, shearing and bending forces can be neutralized and optimal interfragmentary contact and mechanical rest can be achieved (Niederdellmann and Shetty, 1987). A median fracture of the mandible in combination with a bilateral condylar neck fracture presents a problem of miniplate application because of the diastasis of the lingual cortical surface (Fig. 7.**11**). With lag screws the fracture can be perfectly stabilized (Fig. 7.**12**).

Short sagittal fractures may need additional stabilization by a miniplate. In comminuted fractures lag screws are used primarily to simplify the fracture situation. Several fragments can be transformed into a simple fracture with the aid of lag screws, and additional stabilization is achieved by a plate.

Screws placed in lag fashion are also used to reduce condylar fractures, first described by Petzel (1982) and Kitayama (1989) and utilized by Eckelt (Fig. 7.**13**; see also Chapter 10) and Krenkel (Fig. 7.**14**). Lag screws are useful for fixation of inlay and onlay bone grafts. Stable fixation is obtained in various orthognathic procedures, such as genioplasties, subapical osteotomies, and sagittal split ramus osteotomies, as well as in alveolar ridge augmentation procedures. For lamellar fractures, for bone graft fixation and for small fragment fixation a lag screw can be sufficient.

Fig. 7.11 **Median fracture of the mandible in combination with bilateral condylar neck fracture treated with two miniplates in the fracture line.** This has produced a diastasis of the lingual cortical surface

Fig. 7.12 **Median fracture of the mandible with bilateral condylar neck fracture perfectly stabilized by lag screws.** On the inferior border it was necessary to drill a deep hole into the bone to countersink the screw head. Use of a self-adapting spheric washer on the superior border has kept the bone surface intact

△
Fig. 7.13 **Eckelt's technique for treatment of condylar neck fractures.** (See Chapter 10 for further information)

Fig. 7.14 **Krenkel's technique for treatment of condylar neck fractures.** (See also Fig. 10.1) ▷

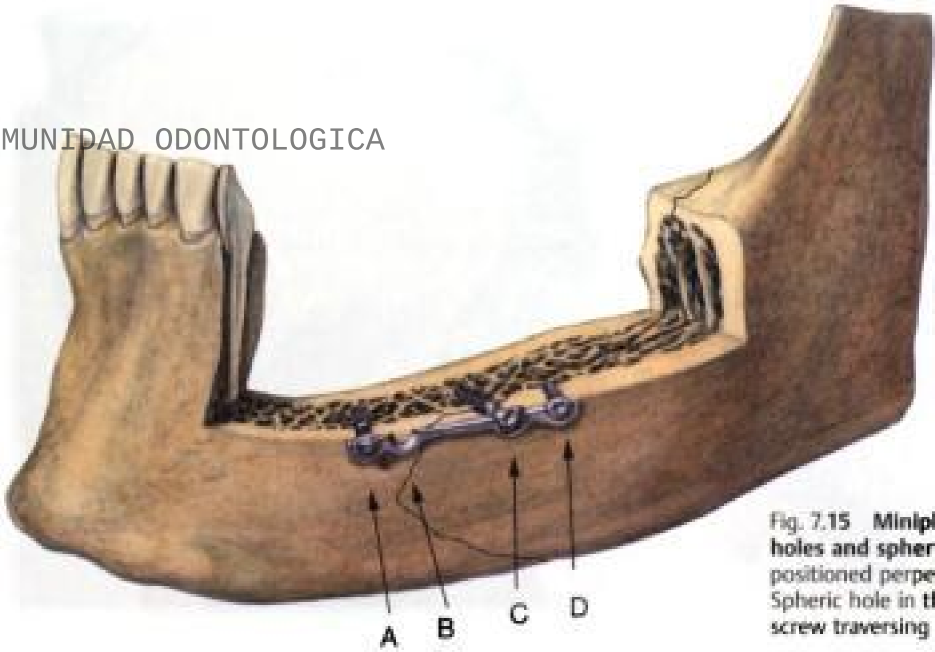


Fig. 7.15 **Miniplate system with spheric screw holes and spheric plate holes.** (A, D) Mini screw positioned perpendicular to the bone surface. (B) Spheric hole in the miniplate. (C) Angulated lag screw traversing perpendicular to the fracture line

When combined with a miniplate osteosynthesis system, the lag screw should have spherical screw heads that coincide with spherical holes in the miniplate (Fig. 7.15). Finally we need a 2 mm drill for the gliding hole preparation, an inlet countersinker and a self-centering sleeve drill guide (see Fig. 7.5).

Lag screws can be applied in an increased range of situations by utilizing a self-adapting washer with spheric hole and eccentric slot. In a median mandibular fracture the screw load is greater. In such a situation a larger 2.7 mm screw, with a core diameter of 2 mm, is necessary. This screw should be combined with the self-adapting spheric washer to prevent bone overload (see Fig. 7.12).

Conclusion

Any screw traversing a fracture should be inserted as a lag screw (Schwimmer, 1993).

Lag screw osteosynthesis is a very sensitive technique; any deviation from the standard lag screw procedure will affect the stability of the result.

To summarize, the advantages of the lag screw technique are:

- minimal hardware requirements;
- the need for few special instruments;
- possibility of application in combination with the miniplate system;
- the direct central application of reduction forces;
- an even distribution of forces on the fragment interface;
- rotational stabilization by close interdigitation of the fracture serration;
- interfragmentary mechanical rest and stability;
- the best conditions for primary bone healing; and
- simple removal of screws.

8 Guided Lag Screw Technique in Mandibular Fractures

Gregory C. Chotkowski

Introduction

Under certain conditions the application of a lag screw can be difficult in mandibular fractures and the direction and position of screws is not always predictable by the conventional lag screw technique. The drill guide developed for extremity traumatology (Müller, Allgöwer, and Willenegger, 1969; Müller *et al.*, 1991) is not practicable in mandibular fractures (Fig. 8.1). For this reason special instruments for guidance of lag screws have been developed, so that fractures of the mandible can be accessed and fixed through a transoral approach, by the guided lag screw technique (Chotkowski, 1997). The exceptions to a transoral approach are:

- severely atrophied mandibles;
- severely comminuted fractures; and
- fractures of the condyle and high condylar neck.

The guided lag screw technique utilizes precision instrumentation together with a specialized screw for the fixation of mandibular fractures (Fig. 8.2). It provides a predictable method of rigid internal fixation with minimal hardware through the use of conservative surgical access in a short operative time (Ellis and Ghali, 1991).

The biomechanics of the mandible give the best preconditions for lag screw application (Rudderman and Mullen, 1992).

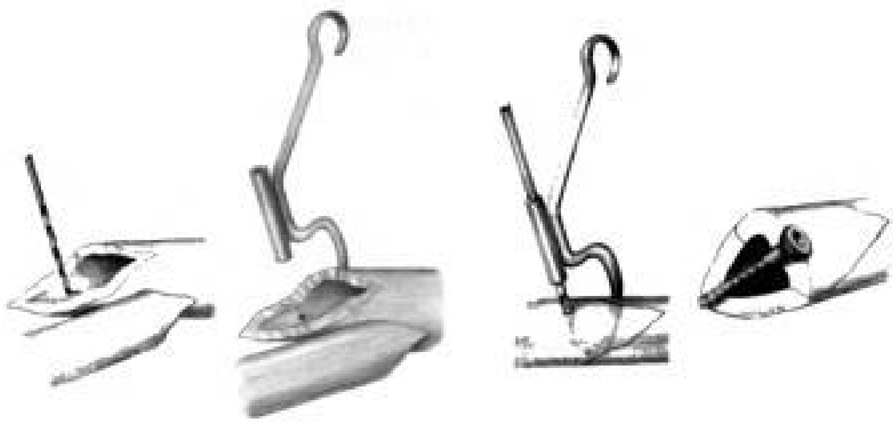


Fig. 8.1 **Drill guide for lag screw technique in extremities.** Application for tibia fracture

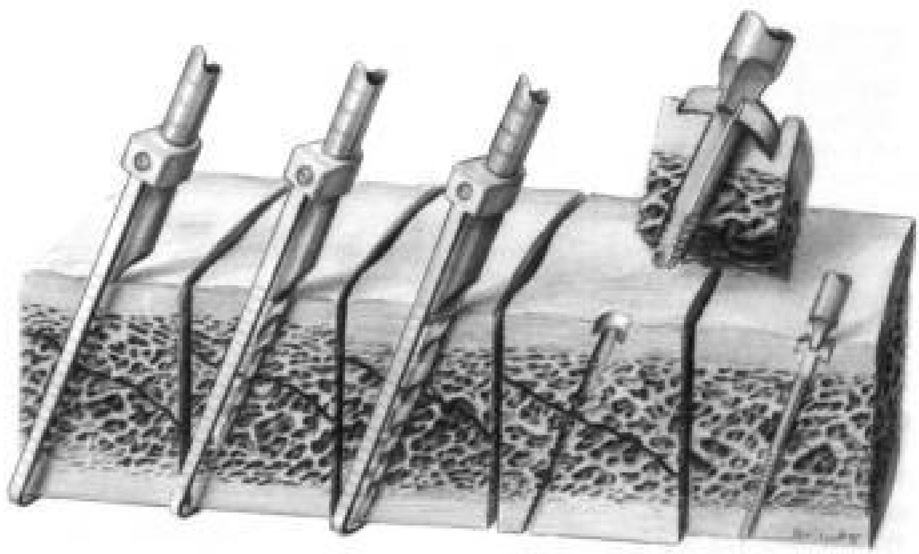


Fig. 8.2 **The application of the screw and the use of the drill guide.** The undersurface of the head of the screw has a biconcave bevel. When the screw is tightened, it directs the compressive forces to the smooth surface of the shaft of the screw. This increases the overall frictional forces of the screw with the bone which, in turn, increase the total compressive forces across the fracture (see also Fig. 7.7 E)

The guided lag screw technique differs from conventional lag screw techniques in that it eliminates uncertainties and decreases the number of operative steps (Fig. 8.3). The drill guide enables the surgeon to adjust the drill bit so that its point of exit can be predicted accurately. This ensures that anatomic structures, roots of teeth and their associated neurovascular bundles will be avoided when drilling. The pointer, which functions as an external depth gauge, runs parallel to the direction of the drill bit and measures the length so that the proper guided lag screw can be selected. Surgical time is also decreased with the use of the stepped drill bit and adjustable countersink. The stepped drill bit tapers from 2.3 mm to 1.7 mm. The countersink, gliding and pilot holes can be prepared in one pass. This reduces the risk of misalignment of the holes that can occur when multiple drill bits are passed.

The Surgical Technique

Stabilization of the Occlusion

The most important aspect of fracture management is to reproduce the occlusion that existed before the injury. The occlusion may be secured by using intermaxillary arch bars, Ernst ligatures, Ivy loops or temporary intermaxillary fixation screws with interarch wires.

Surgical Approach

The recommended surgical approach is transoral. Local anesthesia, with a vasoconstrictor for hemostasis is administered first. The incision is made in the mucobuccal fold, extending through mucosa, muscle and periosteum, or as a marginal rim incision. The dissection is continued down to, and around, the inferior border of the mandible. Important anatomic structures are identified and protected throughout the procedure.

Reduction

The fracture is manually reduced after the fracture site has been cleaned of all debris (i.e. fractured roots, blood clots, and granulation tissue) which may interfere with the absolute reduction of the fracture. Intermaxillary fixation, applied while reducing angle fractures, may assist in maintaining this reduction. Fixation of the fracture should not be attempted until absolute reduction has been achieved. Reduction clamps may be applied to aid in reduction of the fracture (see Fig. 5.2).

General Fixation Technique

Survey the fracture. The tip of the pointer is extended 15 mm beyond the fracture and maintains contact with bone. The beveled end of the drill guide contacts the near cortex. The appropriate angle for screw placement is determined. The pointer is locked into this position (Fig. 8.2).

Adjustment of the drill bit. The stepped drill bit is advanced through the adjustable countersink until it is 2 mm beyond the pointer tip. The countersink is locked into this position (see Fig. 8.3).

Drilling. The drill guide and pointer are reapplied to the mandible. The tip and undersurface of the pointer must maintain contact with bone. The pilot hole, gliding hole and countersink are prepared (see Fig. 8.2).The standard countersink is used to redefine the countersink hole.

Screw placement. The depth gauge is used to measure the guided lag screw hole preparation. The appropriate sized screw is tightened (Fig. 8.2).

Wound closure. After copious irrigation the vestibular incision or the marginal rim incision is closed with a continuous resorbable suture or interdental nylon sutures.

Removal of intermaxillary fixation. At the end of the procedure, the intermaxillary fixation is removed.

Specific Applications of the Guided Lag Screw Fixation Technique

Fixation of mandibular fractures using the guided lag screw technique is best explained for the area of the mandible in which the fracture has occurred (Fig. 8.4).

Fig. 8.3 **Equipment for the lag screw technique. Drill guide, pointer, adjustable countersink and stepped drill bit (A), cross section (B), trocar (C), calibrated drill guide with beveled end (D), adjustable calibrated pointer (E), adjustable biconcave beveled countersink (F), stepped drill bit (G)**

Fig. 8.4 **Mandibular fractures and guided lag screw placement.** Placement is shown for symphysis and parasymphysis fractures, anterior body fractures, posterior body fractures, angle fractures and condylar neck fractures

Symphysis and Parasymphysis Fractures

The guided lag screw technique is performed between the two mandibular canine teeth and the appropriate length screw is placed (Fig. 8.5). An additional screw—especially in sagittal fractures—is placed in the same or opposite direction, to prevent rotation about a single screw. Use of an additional screw is particularly critical with sagittal fractures (Fig. 8.4).

Body Fractures

Some differences in technique are required when the fractures occur around the mental foramen.

For anterior body fractures that occur around or anterior to the mental foramen, surgery is executed from an anterior approach (Fig. 8.6). No additional fixation hardware is needed due to the angle at which the screw crosses the fracture (Fig. 8.4). In cases where there could be possible rotation around a single screw, a second screw or a four-hole monocortical 2 mm plate should be applied.

With posterior body fractures that occur anterior to the mandibular angle region, the lag screw technique is performed at the inferior border, from an anterior approach (Fig. 8.7). An additional four-hole monocortical 2 mm plate may be applied, but is not absolutely essential (Fig. 8.4).

Fig. 8.5 **Symphysis and parasymphysis fractures: proper placement of the drill guide and pointer.** The tip of the pointer extends 15 mm beyond the fracture and is in contact with the lateral surface of the mandible. The undersurface of the pointer must maintain contact with bone during the drilling procedure

Angle Fractures

Third molars must be removed if fractured, mobile, partially erupted, or when interfering with either fracture reduction or screw placement. The guided lag screw technique is performed superior to the neurovascular bundle (see Fig. 8.8). Niederdellmann *et al.* (1976), Weber (1997), and Shetty *et al.* (1995) pointed out that a solitary screw is sufficient fixation for angle fractures.

Fig. 8.6 **Anterior body fractures: proper placement of the drill guide and pointer.** The tip of the pointer extends 15 mm beyond the fracture and is in contact with the inferior border or lingual surface of the mandible. The pointer is angled to allow the drill to pass below the neurovascular bundle. The undersurface of the pointer must maintain contact with the lateral surface of bone during the drilling process

Fig. 8.7 **Posterior body fractures: proper placement of the drill guide and pointer.** The tip of the pointer extends 15 mm beyond the fracture and is in contact with the lingual surface of the mandible. The beveled end of the drill guide is in contact with the lateral surface or near cortex. The undersurface of the pointer maintains equal contact with the inferior border of the mandible during the drilling process. This ensures that the drill bit passes below, and avoids injury to, the neurovascular bundle. (This should not be attempted in cases where there is a low-lying nerve)

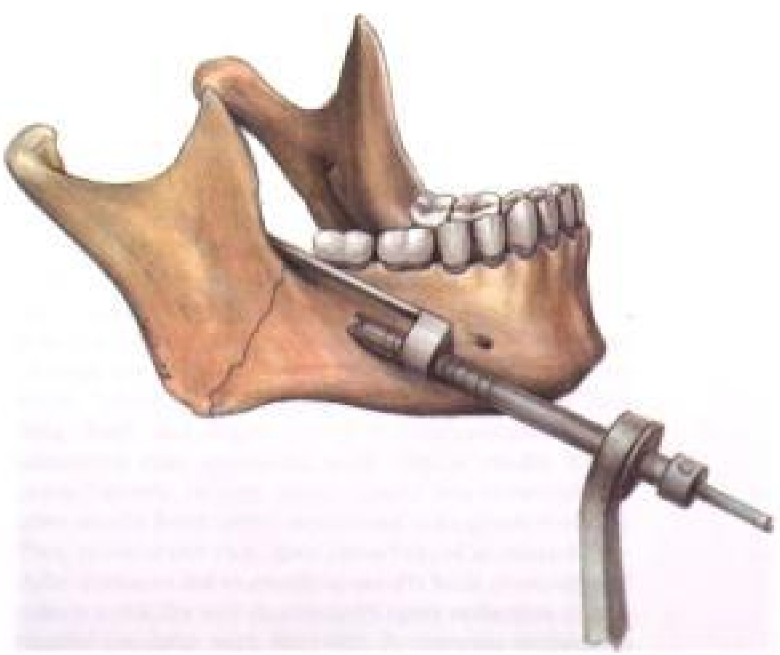


Fig. 8.8 **Angle fractures.** From an inferior anterior approach, the tip of the pointer extends 15 mm beyond the fracture and is in contact with the lingual surface of the ramus, anterior to the lingula. The pointer is angled on an axis that runs parallel to the course of the neurovascular bundle. This axis also runs parallel to the external oblique ridge and ascending ramus. The beveled end of the drill guide is in contact with the widest segment of the external oblique ridge, a minimum distance of 1 cm from the fracture. The undersurface of the pointer maintains equal contact with the superior border and ascending ramus. This ensures that the drill bit passes above, and avoids injury to, the neurovascular bundle. (This should not be attempted in cases where there is a high-lying nerve)

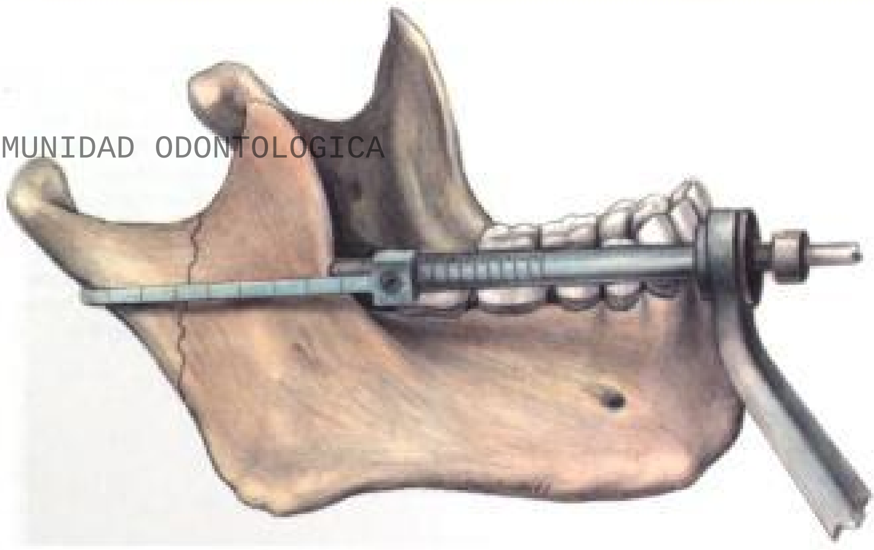


Fig. 8.9 **Condylar neck fractures.** From an anterior approach, the tip of the pointer contacts the posterior lateral surface of the condylar segment. The distance of the tip from the fracture is recorded using the calibration on the pointer. The stepped drill is adjusted and the hole is prepared. For optimal results, the fracture must be reduced and intermaxillary fixation applied prior to fixating

Condylar Neck Fractures

Condylar neck fractures can be approached transorally and fixated using a lag screw if they occur low into the ramus and are not sagittal. An anterior approach is used (Figs. 8.9, 8.4).

Complications

The guided lag screw technique accurately and predictably places screws, avoiding injury to important anatomic structures. However, the system has no emergency screws. In situations where the screw has lost retention, another screw or fixation device may be applied around it. Once the fracture has been secured, the loose screw is removed. In situations of unstable fractures, a period of intermaxillary fixation may be required for healing.

9 Condylar Neck Fractures: What is to be Done?

Franz Härle, Christian Lindqvist, Uwe Eckelt and Klaus Louis Gerlach

The frequency of open reduction of subcondylar fractures varies dramatically between surgeons depending on individual philosophy and the field of practice. The four chapters that follow are contributions on condylar neck fracture treatment describing extraorally applied lag screw osteosynthesis (by Uwe Eckelt), miniplate application by extraoral (Christian Lindqvist) or intraoral (Klaus Gerlach) access, and by extra-intraoral lag screw-plate application (Jürgen Reuther). Another lag screw procedure which, according to Krenkel (1994), follows the same principles as Eckelt is not described in detail. The surgeon must decide on the method of choice.

Management of subcondylar fractures is controversial. Traditionally they have been treated by rigid or elastic intermaxillary fixation followed by physiotherapy. For treating children, this is normally the treatment of choice. Adaptive remodeling will often restore a functional condyle after fracture in children.

In the adult indications for open reduction and internal fixation of subcondylar fractures do exist (Schwimmer, 1988) but are few, perhaps due to the restricted surgical approach. Potential damage to the neurovascular structures is also an inhibiting factor (Raveh *et al.*, 1994). From the literature there is no doubt that conservative treatment in a significant proportion of adult patients is followed by functional disharmony and compromised results (Lindahl, 1977; Zou *et al.*, 1987; Oikarinen, Raustia, and Lahti, 1991; Iizuka *et al.*, 1991). This holds true especially for the MacLennan class III and IV fractures (MacLennan, 1952). Recently Worsaae and Thorn (1994) described that low subcondylar fractures in adults, treated by conservative methods only, often result in complications. These included malocclusion, mandibular asymmetry, restricted masticatory function, malunion or nonunion of fragments, disc displacement, ankylosis and pain at the affected side. In the same study a group of patients treated by open reduction showed minimal complications. On the other hand Iizuka *et al.* (1991) frequently observed rapid resorption of condylar fragments after miniplate osteosynthesis, sometimes within 8 weeks of surgery. They concluded that, when reduction of the condylar fragment is unsatisfactory and the condyle is rigidly fixed in a non physiological position, the risks of postoperative remodeling and aberrant changes are higher because of the increased functional strain. Takenoshita, Ishibashi, and Oka (1990), and Hidding, Wolf, and Pingel (1992) in a comparative study, concluded that apparently good clinical results in the conservatively treated group should not outweigh the poor results from instrumental and radiograph findings. They pointed out that open reduction of displaced condylar fractures led to excellent results both clinically and radiographically and recommend open reduction in dislocated condylar neck fractures. A common problem is the surgical approach (Zide and Kent, 1983; Ellis and Dean, 1993). Fractures where the condylar head is totally dislocated from the glenoid fossa have been traditionally considered to be indicated for open reduction (Tasanen and Lamberg, 1987; Zide and Kent, 1983; Raveh, Vuillemin, and Lädrach, 1989; Mikkonen *et al.*, 1989; Iizuka *et al.*, 1991). Opinions about indications for surgery differ. In fact it is often difficult for surgeons to weigh the advantages and disadvantages of open reduction versus the risk and outcome of a closed procedure.

To avoid the complications of open reductions, the following preconditions should be met:

- there must be sufficient access to and visibility of the fracture site;
- there must be functionally stable fixation;
- other facial bone fractures should be stabilized first, to have a continuous dental arch for application of intermaxillary fixation; and
- bilateral condylar fractures should be operated upon early.

The surgeon should be acquainted with all osteosynthesis techniques. Open reduction of condylar neck fractures is difficult, ambitious and demands an exact surgical technique. It can only be recommended for severely dislocated fractures (MacLennan IV) and fractures where significant shortening (> 8 mm) of the ramus (MacLennan III) can be diagnosed (Silvennoinen *et al.*, 1994).

10 Condylar Neck Fractures: Lag Screws

Uwe Eckelt

Introduction

The primary aim of the treatment of condylar neck fractures is the restoration of an undisturbed function of the temporomandibular joint. One method is the lag screw osteosynthesis (see Chapter 7) to achieve a stable fixation of the fragments, primary bone healing and early mobilization to restore the functions of the joint.

Wackerbauer (1962) and Petzel (1980) first described a method of performing lag screw osteosynthesis of condylar neck fractures via a submandibular approach, using long lag screws. Stephenson and Graham (1952), and later Timmel (1981) reported on fixation with Kirschner wires, starting in front of the auricle, which however required a transarticular approach. Takenoshita, Oka, and Tashiro in 1989 introduced a combined surgical procedure utilizing preauricular and submandibular approaches using Kirschner wires. An intraoral lag screw method was described by Kitayama in 1989. Krenkel (Krenkel and Lixl, 1988; Krenkel, 1992) developed a method of lag screw osteosynthesis of the condylar neck fracture by a submandibular approach, using a lag screw with a biconcave anchor washer to prevent microfractures (Fig. 10.**1**). Kuttner (1989) has demonstrated that lag screws with biconcave washers (anchor washers) can be turned twice as tightly as screws without washers before cracks occur in the bone. Eckelt (Eckelt and Gerber 1981; Eckelt, 1984) developed a special nut and screw for lag screw osteosynthesis of condylar neck fractures via a special surgical periangular approach (Fig. 10.**2**).

Fig. 10.1 **Principle of lag screw osteosynthesis according to Krenkel, at the condylar neck of the mandible**

Indication

Use of this technique is indicated in:

- displacement, when the condylar head deviates medially more than 30°; and
- fractures with a significant dislocation or contraction of the fragments of more than 5 mm or lack of bone contact in the fragments.

Instruments

For secure execution of lag screw osteosynthesis, special surgical instruments have been developed. These include lag screws with diameters of 2 mm and 2.3 mm. The latter is used as an emergency screw only (Fig. 10.**3**).

The lag screws are 45–70 mm in length, in increments of 5 mm. The screws have a cortical thread of 10 mm at one end and at the other a metric machine thread. At this end they have a square head which fits a special square spanner for insertion of the screws (Fig. 10.**4**). Interfragment pressure is caused by screwing a nut onto the lag screw at the mandibular base. The nut has a sleeve 6 mm long, projecting into the gliding channel, and is fitted against the base of the mandible (Fig. 10.**5**).

In addition, a special mill has been developed for creating a level surface at the base of the mandible and a depth gauge for determining what length of lag screw is required.

For drilling in the condylar process, a special drill with a cutting length of only 10 mm has been developed; this ensures that drilling beyond the process does not occur. The gliding channel is created by a Lindemann mill with a length of 35 mm. To extend the gliding channel, espe-

Fig. 10.2 **Principle of lag screw osteosynthesis according to Eckelt, at the condylar neck of the mandible**

Fig. 10.3 **Range of lag screws**

Fig. 10.4 **Square spanner suitable for the lag screw**

Fig. 10.5 **Nut and special spanner**

Fig. 10.6 **Condylar drill, depth gauge, countersink, and twist drill**

Fig. 10.7 **The mandible is pulled down with a single-forked hook to facilitate reduction of the condylar fragment**

cially at the upper part where the Lindemann mill ends in a point, twist drills of 2 mm and 2.3 mm are available (Fig. 10.**6**).

Surgical Technique

For the surgical approach to the joint, a skin incision of 4 cm is made at the mandibular angle. When positioning the patient, a roll has to be placed under the shoulders so that the head is slightly inclined. This is the only way to direct the drills into the mandibular ramus without being impeded by the patient's thorax.

After the skin incision the platysma is exposed to about 1 cm above the border of the mandible. Here the fasciae of the masseter muscle are bluntly dissected carefully and the marginal ramus of the facial nerve is identified using a nerve stimulator. The masseter muscle is cut above the marginal ramus nerve, which is now displaced caudally to avoid it being traumatized by the retractor that will be used later to ensure good vision of the operating field (see Figs. 3.**17**, 3.**18**). This procedure has proved advantageous; no permanent damage of the facial nerve has been seen.

After dividing the masseter muscle the mandible is exposed. A hole is drilled into the mandibular angle and the ramus pulled caudally with a bone hook (Fig. 10.**7**). This makes surveying the joint area and preparing the fracture site easier. Repositioning the condylar process is often only possible by gliding a periosteal elevator medially alongside the ramus, which relocates the condyle in the articular cavity.

With severely dislocated fractures this is often not sufficient. A repositioning forceps has been developed especially for the right and left side of the mandibular ramus which allows the condyle neck to be seized and repositioned in its former situation (Fig. 10.**8**).

A third way of repositioning is to fasten a special repositioning pin in the condyle through the skin of the cheek by means of a trocar. In this way the condyle can be moved and repositioned in its former place (Fig. 10.**9**).

Repositioning the condyle is very difficult, requiring all the skill and experience of an experienced surgeon.

After repositioning, a groove of 10–15 mm is created in the outer cortex extending caudally from the fracture. This groove indicates the direction of the later gliding channel (Fig. 10.**10**). This 'window' in the outer cortex permits a good view on the tip of the drill. It can be directly observed when later drilling into the condylar head, whether the drill tends to glide medially or laterally at the fracture surface. This is especially important for oblique fractures. After creating this window in the outer cortex, the direction of the gliding channel from the base of the mandible is determined by setting a mark with a round burr at the corresponding place on the mandibular base (Fig. 10.**11**).

Fig. 10.8 **Left side repositioning forceps**

Fig. 10.9 **A repositioning pin in the condyle through the skin of the cheek placed using a trocar**

Fig. 10.10 **A 10–15 mm long groove in the outer cortex, extending caudally from the fracture line, is created using a round burr**

Fig. 10.11 **The bone surface at the mandibular base is flattened using a round burr**

Fig. 10.12 **A Lindemann reamer is used to create the gliding channel, starting from the mandibular base**

Fig. 10.13 **Extension of the groove in the outer cortex of the small fragment**

Fig. 10.14 **A countersink is used to create a level surface for the nut**

Starting from this point the gliding channel is made in the mandibular ramus with the Lindemann bone drill (Fig. 10.**12**). If the ramus is sufficiently wide, the Lindemann drill glides upwards, between the outer and inner cortex, and the window in the outer cortex is reached. If the ramus is extremely thin, the gliding channel may be open over a longer distance. Normally this does not impair stability of the osteosynthesis. Necessary adjustments of direction of the gliding channel can be made using the Lindemann bone drill. Special retractors have been developed to protect soft tissues at the base of the mandible while milling the gliding channel.

Execution of lag screw osteosynthesis is especially difficult where the ramus is narrow and in oblique fractures. In these cases the groove from the outer cortex into the small fragment is extended so that there is sufficient thickness of bone in the upper part of the condyle to give a good position for drilling into the condyle (Fig. 10.**13**). After the gliding channel is finished, a level base for the nut has to be created at the base of the mandible (Fig. 10.**14**). Next the 10 mm drill is bored into the condyle (Fig. 10.**15**). The length of the lag screw needed is determined (Fig. 10.**16**) and the screw, is then screwed into the condyle (Fig. 10.**17**). When the nut at the base of the mandible is tightened, the osteosynthesis is functionally stable (Fig. 10.**18**). The patient can move the mandible directly after surgery.

A functional treatment with maxillo-orthopedic appliances is not necessary.

Fig. 10.15 **The condyle is bored using a 10 mm drill**

Fig. 10.16 **Measuring the length of the lag screw**

Fig. 10.17 **Screwing the lag screw into the condyle**

Fig. 10.18 **Interfragmentary compression is created by tightening the nut at the mandibular base**

Removal of Osteosynthesis Material

The lag screw is removed under local anesthesia after 4–6 months by a stab incision in the old scar without exposing the joint. After the nut has been removed, the screw is extracted. Ease of removal of osteosynthesis materials is the most important advantage of this technique over other functionally stable methods.

11 Condylar Neck Fracture Miniplates: Extraoral Approach

Christian Lindqvist and Tateyuki Iizuka

Introduction

Early mobilization and functional rehabilitation are considered important in the treatment of condylar neck fractures (Upton, 1991). The goal of surgery is to provide adequate stability to the fracture to allow immediate function (Michelet, Deymes, and Dessus, 1973; Koberg and Momma, 1978; Pape, Hauenstein, and Gerlach, 1980; Chuong and Piper, 1988).

Indication

Simple radiographic measurements (panoramic, radiograph and Towne's view) are used to identify difficult condylar fractures. Silvennoinen *et al.* (1994) found that fractures with marked reduction in ramus height, irrespective of presence or absence of condylar displacement, frequently result in occlusal and functional disturbances (Figs. 11.**1**, 11.**2**, 11.**3**). Condylar displacement from the fossa is not the only deciding factor. Where the condyle is still in the fossa, reduction of more than 8 mm in ramus height is frequently associated with a therapy-resistant occlusal change. In cases in which the condyle is dislocated from the glenoid fossa, overriding is also evident. Because of condylar displacement, marked reduction of ramus height is also observed (mean 10.3 mm). We thus consider traumatic reduction of more than 8 mm in ramus height as an indication for surgery. In 1992 in a study on different patterns of condylar fractures, Silvennoinen *et al.* pointed out that 15% of patients were retrospectively considered to have had an indication for open reduction.

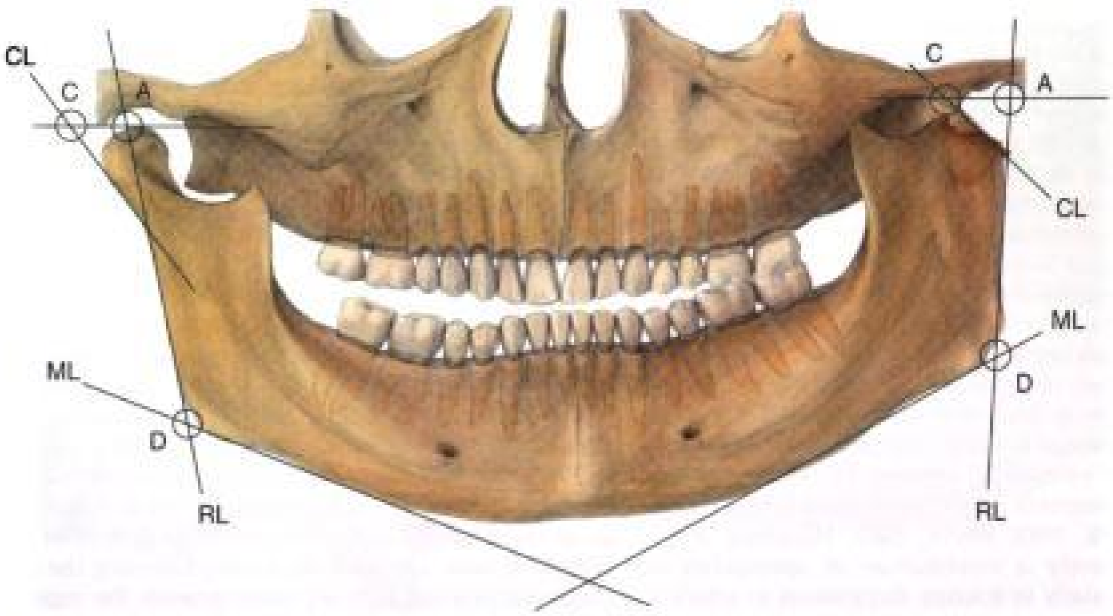


Fig. 11.1 **The method of radiologic measurement.** Ramal height is the distance between the mandibular line (ML) and a tangent to the superior point of the condyle (CA) measured along the ramus line (RL) on the fractured and non-fractured sides (from point A to point D). Reduction of ramus height is represented by the difference in length between the fractured and non-fractured sides. Mandibular line is the tangent to the lower border of the mandible

Fig. 11.2 **Dislocation.** The fracture is considered to be dislocated when the condyle is located in front of the lowest point of the articular eminence or when the angulation in an oblique frontal projection (Towne's view) is more than 50°

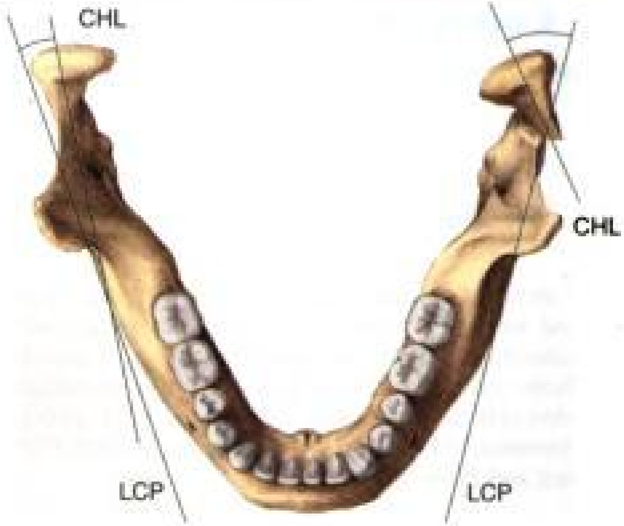


Fig. 11.3 **Measurement of fracture angle.** Angulation of the fractured and non-fractured condylar processes is measured in the oblique frontal projection as the difference between a mid-condylar line (CHL) and a line along the lateral cortical plate (LCP) of the mandibular ramus. Angulation of the fractured side is represented by the difference in degree between the fractured and non-fractured sides

Surgical Approaches

Two main approaches are preferred, the preauricular approach and the retromandibular approach, with the rhytidectomy (face-lift) approach as a modification (Fig. 11.**4**). The level of the fracture and the degree of displacement are the most important factors in selecting the approach. Preauricular incision is the most direct approach to high subcondylar and neck fractures. It is especially useful for fracture displacements where medial exploration is desired with the potential for surgical manipulation of soft tissues within the joint (Chuong and Piper, 1988). On the other hand, access to the ramus fragment is often too limited to expose enough space for a miniplate. A retromandibular approach provides good access in cases of low subcondylar fractures and more space for placing the plate and screws. Subcondylar fractures and fractures extending into the upper ramus region are best addressed using the retromandibular approach. However, reduction of the medially dislocated condyle is often difficult due to the limited access. In severe anteromedial fracture dislocations an additional vertical ramus osteotomy, followed by removal of the osteotomized segment might be necessary (Ellis, Reynolds, and Park, 1989; Boyne, 1989; Mikkonen *et al.*, 1989). Occasionally a combination of approaches is needed, particularly in fracture dislocations in which a preauricular approach may be necessary to retrieve the condylar segment, while fixation is performed through a retromandibular approach (Takenoshita, Ishibashi, and Oka, 1990).

Surgical Technique

The preauricular approach (Al-Kayat and Bramley, 1979) is recommended.

The Preauricular Approach

The skin incision is carried through the skin and superficial fascia to the level of the temporal fascia. This layer is dissected downwards, along, and posterior to, the temporal vessels, until the lower end of the skin incision is reached. Then the posterior end of the zygomatic arch can be palpated easily. At a point about 2 cm above the zygomatic arch the temporal fascia splits into the lateral and medial layers. The pocket formed by the division of the temporal fascia contains fatty tissue, which is visible through the thin lateral layer (Fig. 11.**5**). Starting at the root of the zygomatic arch, an incision running at 45° to 60° upward and forward is made through the superficial layer of the temporal fascia. Once inside this pocket, the periosteum of the zygomatic arch can be safely incised and reflected forward as one flap with the outer layer of the temporal fascia. The flap can be raised anteriorly, as far as the posterior border of the frontal process of the zygomatic bone, and caudally, closely following the cartilaginous external auditory canal beneath the superficial temporal vessels and the glenoid lobe of the parotid gland (Fig. 11.**6**). As the temporal vessels cross under the branches of the facial nerve, the nerves are safely embedded in the flap. Until the flap is elevated, the tem-

Fig. 11.4 **Skin incisions for three common approaches to the temporomandibular joint.** Temporopreauricular incision (dashed line), rhytidectomy incision (dotted line), retromandibular incision (solid line). (after Albrecht Dürer, *St. Apollonia* 1521 Kupferstichkabinett, Berlin)

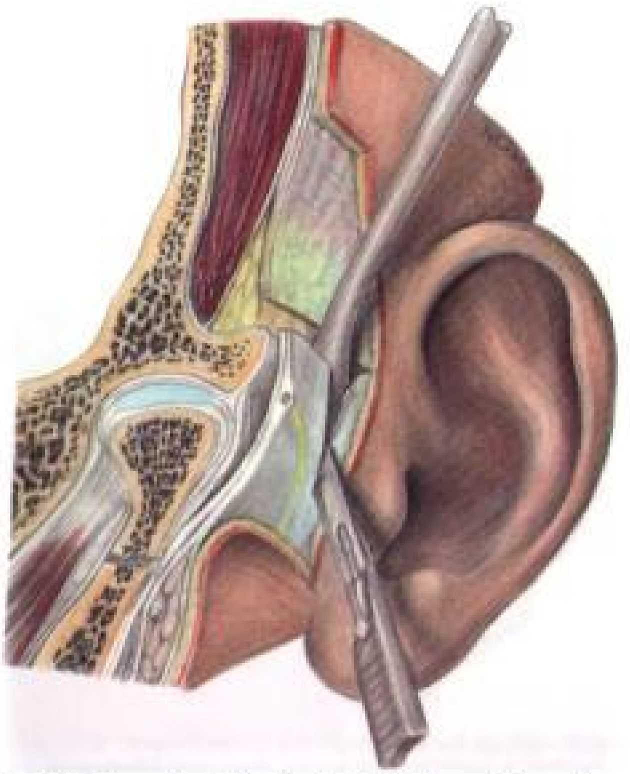


Fig. 11.5 **Coronal section showing the layer of dissection.** The position of the temporal branch of the facial nerve during exposure of the temporomandibular joint by preauricular approach is shown

Fig. 11.6 **Preauricular approach to the temporomandibular joint**

poral vessels are left intact as an important landmark. Proceeding downward from the lower border of the zygomatic arch and articular fossa, the tissues lateral to the joint capsule are dissected and retracted until the neck of the condyle is exposed.

The Retromandibular Approach

The retromandibular approach was described by Ellis, Reynolds, and Park (1989).

The skin incision begins 0.5 cm below the lobe of the ear and continues inferiorly for 3–3.5 cm. It is placed just behind the posterior border of the mandible and usually does not extend inferiorly below the level of the mandibular angle. The dissection is carried through skin, subcutaneous fat and the platysma muscle to the parotid gland. After entering the parotid capsule, blunt dissection begins in an anteromedial direction towards the posterior border of the mandible. The marginal mandibular and cervical branches of the facial nerve will frequently be encountered during this dissection. The cervical nerve is of no consequence because it is usually running vertically out of the operation field. The mandibular branch must be retracted either superiorly or inferiorly depending on its location. Once the nerve is retracted, the pterygomasseteric sling can be readily exposed at the posterior border of the mandible. The retromandibular vein runs vertically in the same plane of dissection and is commonly exposed along its entire course. This vein rarely requires ligation. The periosteum along the posterior border of the mandible and partially around the mandibular angle is incised, from as far superiorly as is reachable, to as far inferiorly around the gonial angle as is possible (Fig. 11.7). The periosteum and the masseter muscle are then stripped from the ramus.

Rhytidectomy Face-lift Approach

The incision for the rhytidectomy face-lift approach differs from that of the retromandibular approach. It employs the more hidden cutaneous incision that was originally used for the face-lift (Zide and Kent, 1983) and recently described by Anastassov *et al.* (1997) for exposing posterior mandibular fractures. The incision begins approximately 1.5–2 cm superior to the zygomatic arch, just posterior to the anterior extent of the hairline. From this point the incision curves posteriorly and inferiorly, bending into a preauricular incision in the neutral crease anterior to the pinna. The incision continues under the lobe of the ear and posteriorly in the lobular fold and then curves superiorly. The incision extends approximately 3 mm onto the posterior surface of the auricle. This modification prevents a noticeable scar, which occurs during contraction of the flap, from being visible in the mastoid region. Instead, the scar ends up in the crease between the auricle and the mastoid skin. When the incision is at a point where it is well hidden by the ear, it curves posteriorly toward the hairline. It then runs along the hairline—or just inside it—for a few centimeters. A skin flap is elevated with sharp and blunt dissection. The flap must be widely undermined so that a subcutaneous pocket is created that extends below the mandibular angle and a few centimeters anterior to the posterior border of the mandible. If one stays in the subcu-

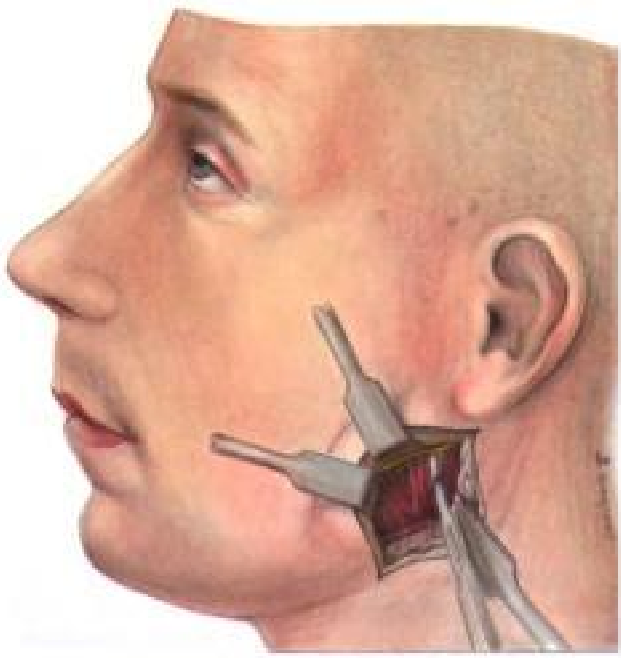


Fig. 11.7 **Retromandibular approach to the temporomandibular joint.** (after Franco-Flamish Master, **Portrait of Wencelas of Luxembourg, Duke of Brabant**, ca. 1405–1415)

Fig. 11.8 **Rhytidectomy approach to the temporomandibular joint.** (after Franco-Flamish Master, **Portrait of Wencelas of Luxembourg, Duke of Brabant**, ca. 1405–1415)

taneous tissue, there are virtually no anatomic structures of any clinical significance. Once the skin has been retracted anteriorly and inferiorly, the soft tissues overlying the posterior half of the mandibular ramus will be seen (Fig. 11.8). From this point on the dissection proceeds exactly as described for the retromandibular approach.

Osteosynthesis Technique

When the preauricular approach is used, the condylar neck is first exposed, and the condyle is localized. In case of medial displacement, the fossa is empty, and usually only the distal border of the condylar fragment, which is at an angle to the ascending ramus, is visible. Repositioning of the condyle into the fossa takes place by careful lateral traction using hooks, periosteum elevators, or both (Fig. 11.**9**). After repositioning the condyle into the fossa, the distal end of the fragment is adapted to the stump of the ascending ramus and is maintained by rigid intermaxillary fixation (Fig. 11.**10**). The fracture is fixed monocortically, using a miniplate on the lateral surface. Because access below the fracture is limited with the preauricular approach, plating may involve using a transcutaneous trocar to aid placing the most inferior screws (Fig. 11.**11**). As another alternative, an L-shaped plate can be used, with both screw holes at the same level below the fracture line (Fig. 11.**12**). To achieve a functionally stable fixation that avoids resilient movements of the condylar fragment, at least two screws should be used on each side of the fracture.

When the retromandibular approach is used, repositioning of the condylar fragment is undertaken using a hooked clamp or forceps. Osteosynthesis is performed using a straight four-hole miniplate. To achieve more rigid stability, screws of 2 mm diameter are recommended (Ellis and Dean, 1993). Bicortical screws may also be used. If the condyle is severely displaced in the medial direction, it is often difficult to locate the fractured fragment. To achieve a better access to the condyle, one option is the use of the osteotomy–osteosynthesis technique (Ellis, Reynolds, and Park, 1989; Boyne, 1989; Mikkonen *et al.*, 1989) in which a vertical osteotomy is performed from the sigmoid notch to a point 1.5 cm

Fig. 11.**9** **Repositioning a medially luxated condyle through a preauricular approach.** Inferior traction of the mandible is accomplished through a clamp placed percutaneously, which the assistant pulls downward. (after Jacopo Tintoretto, **Portrait of a Senator**, ca. 1580, Foundation Museum Bornemisza, Madrid)

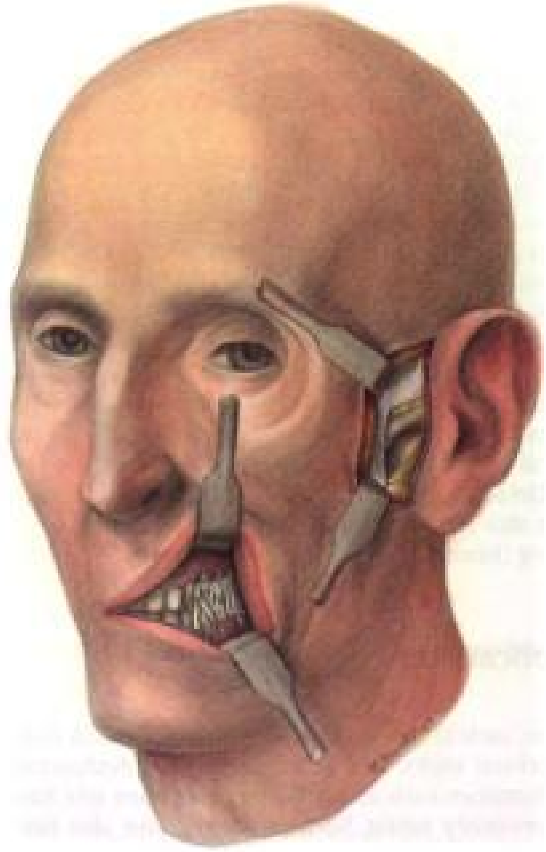


Fig. 11.**10** **The condyle is now repositioned and intermaxillary fixation is applied.** (after Jacopo Tintoretto, **Portrait of a Senator**, ca. 1580, Foundation Museum Bornemisza, Madrid)

Fig. 11.11 **Miniplate osteosynthesis with a six-hole plate.** A transcutaneous trocar is used to facilitate placing of the three inferior screws

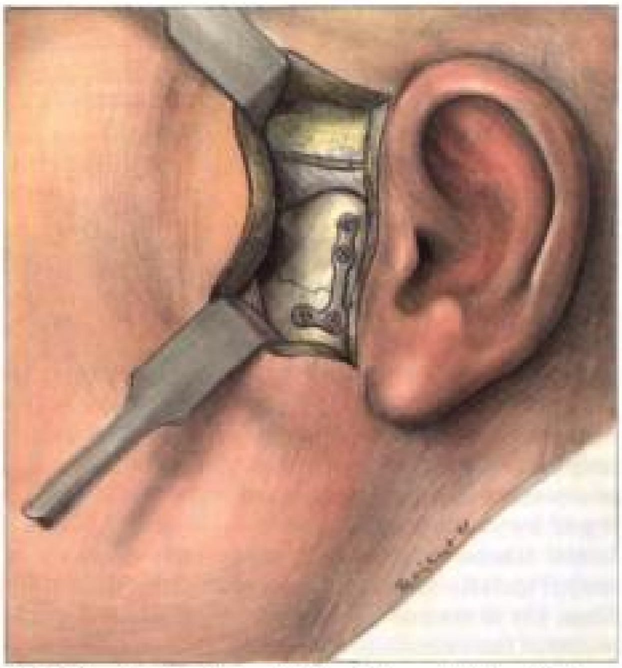


Fig. 11.12 **Another alternative is a L-shaped plate which can be applied without the use of a trocar**

above the posterior border of the mandible and then posteriorly through the posterior border. After removing this segment of bone, there is unlimited access to the lateral pterygoid muscle and the displaced condyle. The condyle can then be distracted into position and a plate applied. The condylar head usually remains attached to the lateral pterygoid muscle. In some cases, it may be necessary to totally remove the condyle and perform osteosynthesis extracorporeally. Rigid fixation with plates is carried out between the ramus segment and condylar head. The unit is returned as a free autogenous bone graft, and the osteotomy is plated. The complete removal of the condyle and ramus fragment seems a radical procedure, but few irreversible changes were seen in a clinical and radiological follow-up (Mikkonen *et al.*, 1989). Detachment of the condyle during reduction and fixation also had no effect on the rate and degree of remodeling (Iizuka *et al.*, 1991).

Complications

Problems such as limited opening interfering with function, occlusal shifts, late arthritic changes, dysfunction and deformities such as asymmetry and open bite have been previously noted. Such problems have also been noted with closed reductions (Jeter and Hackney, 1992). Hemorrhage and development of a haematoma are possible. Some patients have motor weakness of the lower lip at the immediate postoperative stage. This damage is temporary and is considered to be caused by tension in the surrounding soft tissues during surgical procedure. No damage to the facial nerve was observed in any cases operated on via the preauricular approach. The risk of auriculotemporal syndrome in connection with a preauricular approach is low (Swanson, Laskin, and Campbell, 1991). The most severe complication is described by Iizuka *et al.* (1991). One patient had persistent joint pain and limited mouth opening with a total condylar resorption, after extraoral miniplate osteosynthesis, which made a subsequent arthroplasty with an autogenous costochondral graft necessary.

12 Condylar Neck Fracture Miniplates: Intraoral Approach

Klaus Louis Gerlach

Introduction

The indication for surgical treatment is condylar neck fractures where the dislocated proximal fragment is in such an unusual position that purely conservative treatment does not guarantee any success. The risk of damaging the facial nerve, which exists in open reduction via an extraoral approach is avoidable when using intraoral access. It was first described by Silverman (1925) and later on recommended by Steinhäuser (1964). Pape, Hauenstein, and Gerlach (1980) first presented a larger series with miniplate osteosynthesis of condylar neck fractures after an intraoral approach. In a later follow-up, published by Horch, Gerlach, and Pape (1983), the poor results in some cases were explained by access difficulties and the indication for this approach was only for low condylar fractures when the fracture line was running through the sigmoid notch. Later on, further recommendations for an intraoral approach were given by Jeter, van Sickels, and Nishioka (1988), Lachner, Clanton, and Waite (1991), Ellis and Dean (1993), Nehse and Maerker (1996), and Hochbahn *et al.* (1996). The difficulties previously described, involving access and control of the reduced condyle fragments, had been solved by using a right-angle drilling and screwdriving instrument (Fig. 12.1) and by the addition of endoscopic monitoring (Fritzemeier and Bechthold, 1993; Mokros and Erle, 1996; Gerlach, Mokros, and Erle, 1996).

Fig. 12.1 **Right-angled drilling and screwdriving instrument**

Surgical Approach

The condylar neck is approached through an incision over the anterior border of the ascending ramus extending into the lower buccal sulcus. The temporalis muscle is stripped from the anterior border and the masseter is reflected laterally by subperiostal dissection. Soft tissue reflection is enhanced by a special retractor placed at the dorsal border of the ramus. An additional notched retractor at the anterior border of the coronoid process allows good inspection of the sigmoid notch and the coronoid process (Figs. 12.2, 12.3). The periosteum of the proximal segment is then elevated cranially for about 1 cm, which is necessary to position the plate.

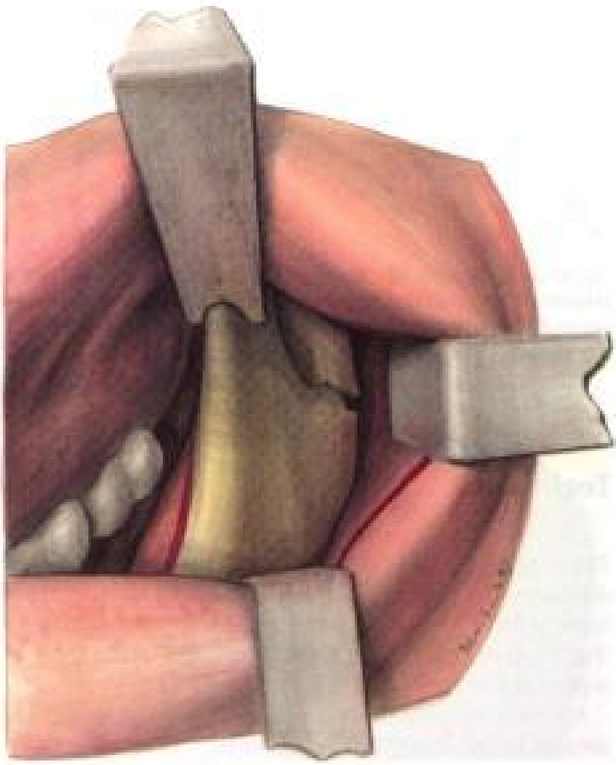


Fig. 12.2 **Intraoral surgical approach to the condylar neck**

Fig. 12.3 **Exposure of the condylar neck using a notched retractor at the anterior border of the coronoid process and a second retractor placed at the dorsal border of the ascending ramus**

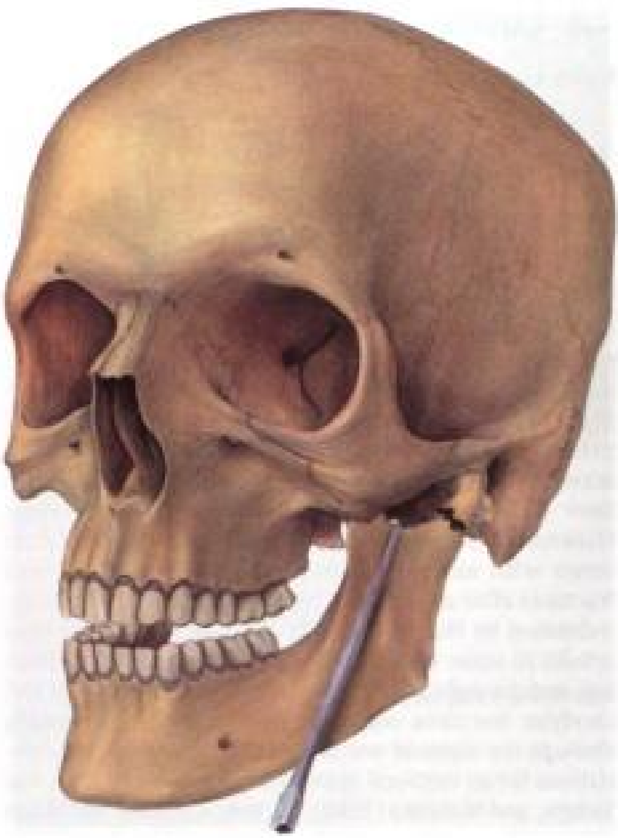


Fig. 12.4 **A sharp hook placed into the sigmoid notch allows the anterior fragment to be displaced caudally, so enabling the condyle to be repositioned**

Technique

The repositioning of the condyle fragment is aided by displacing the anterior fragment caudally using a sharp hook which is placed either into the sigmoid notch (Fig. 12.**4**) or in a special bore hole made in the anterior aspect of the ascending ramus (Fig. 12.**5**).

A bent four-hole plate is then adapted so that it lies parallel to the dorsal border of the ascending ramus with two holes covering each fragment.

The plate is removed, the proximal fragment is moved laterally and a hole is prepared with a right angle drilling instrument (Fig. 12.**6**).

A 5 mm screw together with the plate is attached to the right-angled screwdriver by the aid of a fixing clip and placed over the drill hole in the dislocated proximal fragment. For this purpose the use of center-drive screws is convenient (Fig. 12.**7**). After the first few turns of the screw, when it threads into the bone, the plate-securing fixing clip is pushed away and tightening is continued. Following this, the second screw is inserted into the proximal fragment.

The condylar fragment is repositioned, occlusion is established by temporary intermaxillary wiring and the reduction of the fragments checked with an endoscope. The remaining screw holes in the distal fragment are drilled, the screws inserted and tightened (Figs. 12.**8**, 12.**9**, 12.**10**).

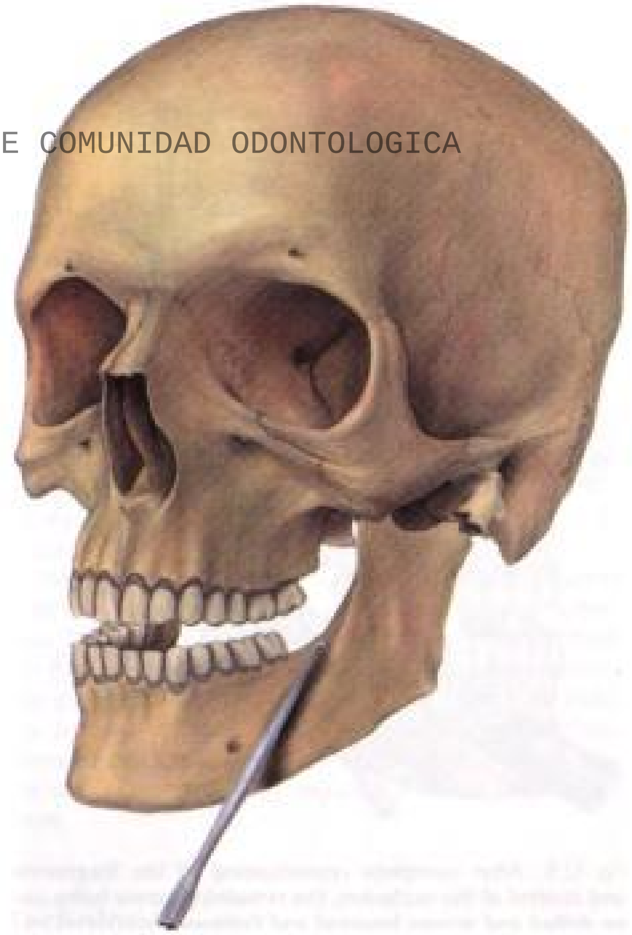


Fig. 12.5 Here the sharp hook is placed in a special bore hole in the anterior aspect of the ascending ramus to displace the anterior fragment caudally

Fig. 12.6 A bore hole is prepared with the right angle drill in the proximal fragment

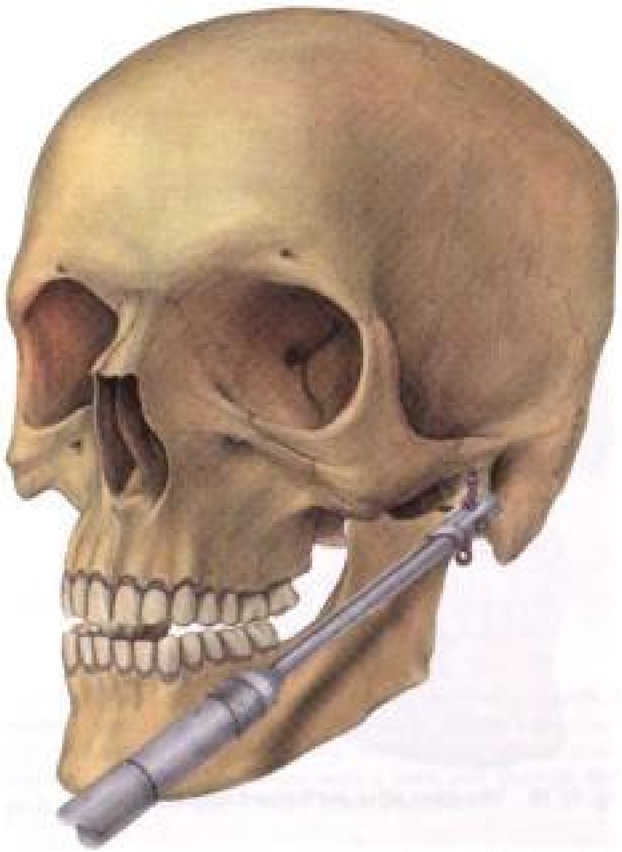


Fig. 12.7 A 5 mm center-drive screw together with the miniplate is attached to the right-angled screwdriver close to the fracture at the dislocated proximal fragment

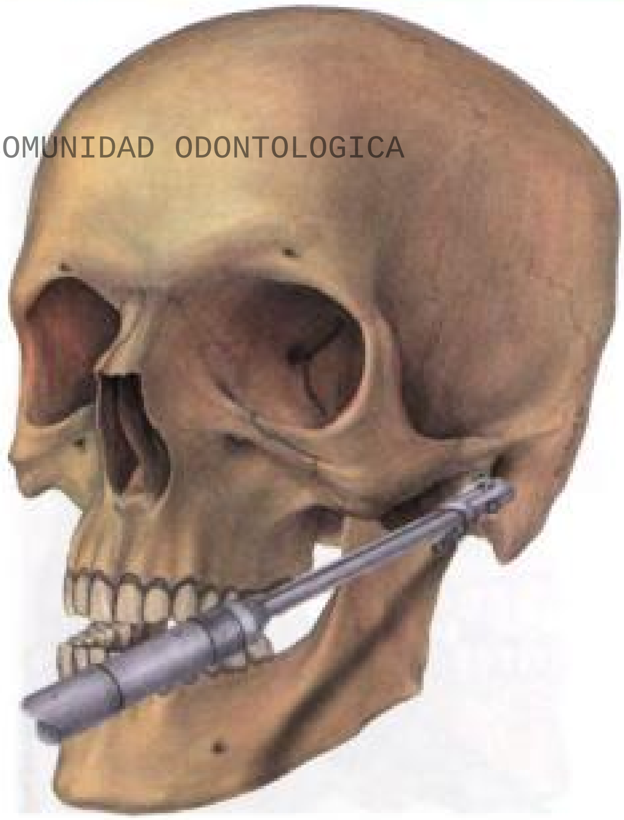


Fig. 12.8 **The second screw is placed into the proximal fragment**

Fig. 12.9 **After complete repositioning of the fragments and control of the occlusion, the remaining screw holes can be drilled and screws inserted and tightened**

Fig. 12.10 **Situation after performed osteosynthesis**

As an alternative to the use of a right-angled drilling and screwdriving system, insertion and tightening of the screws may be performed transcutaneously. For this a trocar is inserted in the preauricular region for the instrumentation. Drilling is done via the trocar. The adapted osteosynthesis plate is transferred through a transoral incision and aligned over the drill holes, the screwdriver with the attached screws is inserted through the trocar and the screws are tightened. It is recommended that the plate should be secured to the condyle fragment first, as previously described, and the reduction confirmed before the plate is secured to the ramus.

A perioperative antibiotic prophylactic and the use of suction drainage are also recommended.

The operative repositioning and fixation of condylar fractures by miniplates via an intraoral approach is comparatively difficult because of limited access. Therefore this method is especially recommended for laterally and—with some restrictions—for medially dislocated subcondylar fractures. In the case of luxation of the condyles out of the fossa, an alternative extraoral approach should be preferred.

Confirming the reduction by endoscopic examination avoids postoperative complications. Further advantages of this technique are the avoidance of visible scars and the minimized risk of damage to the facial nerve. A further advantage (Ellis and Dean, 1993) is familiarity that surgeons have with this approach, which is used during transoral vertical ramus osteotomy.

13 Condylar Neck Fracture: Lag Screw Plates

Jürgen Reuther

Introduction

Reliable fixation and sufficient fragment stability cannot always be achieved with lag screws and plates (Petzel, 1982; Hidding, Wolf, and Pingel, 1992; Krenkel, 1994; Ziccardi, Schneider, and Kummer, 1997) due to the aforementioned variations in bone thickness in the ascending ramus. To address this problem a combination of lag screws and miniplate rigid fixation using special instruments has been developed. The advantages of the technique are highlighted here.

The gliding hole in the lag screw plate allows the screw to be moved to ensure better interfragmentary compression. The plate is secured at a distance of 5–8 mm from the fracture line, at the posterior border of the ramus. The guide sleeve at the upper end of the lag screw plate has an angle of inclination of 10° to the bone surface. Through this guide sleeve the lag screw is inserted into the small fragment, thus securing it to the larger fragment.

Technique

In slightly displaced condylar neck fractures the large fragment is exposed by an extraoral approach. It is slightly contoured from a buccal direction with a bone burr and then milled with a diamond-coated grooved cutter, with the groove pointing to the center of the small fragment and parallel to the posterior border of the ramus (Fig. 13.**1**). The plate is pre-fixed in the milled recess with a fixation screw in the middle portion of the gliding hole. The distance of the plate from the fracture gap is determined by the thickness of the condylar neck and by the 10° angle of inclination of the guide sleeve. As a rule, this distance is 5–8 mm, which presupposes a condylar neck thickness of about 5 mm in the area of the fracture. Then the condylar neck fracture is reduced. The medulla of the small fragment is pre-drilled with a twist drill through the guide sleeve in the plate (Fig. 13.**2**) and the lag screw is tightened. Often, the screw can be placed and tightened without pre-drilling. If the thread strips, a longer lag screw can be used. After the fragment has been reduced satisfactorily, final fixation is performed by tightening the bone screws in the gliding hole and in the posterior fixation hole of the plate (Fig. 13.**3**). If the lag screw cannot be sufficiently secured in the small fragment, then the system can only be used for fragment positioning and immobilization has to be achieved with intermaxillary fixation.

In severely displaced condylar neck fractures the large fragment has to be exposed by an extraoral approach and it is centered, milled and pre-drilled, as described before

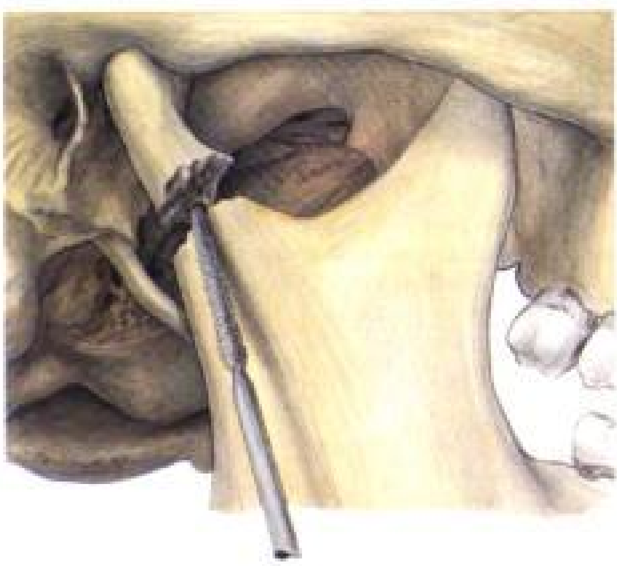


Fig. 13.1 **The large fragment is slightly contoured from a buccal direction with a bone burr and then milled with a diamond-coated grooved cutter, with the groove pointing to the center of the small fragment and parallel to the posterior border of the ramus**

Fig. 13.2 **The plate is pre-fixed in the milled recess with a fixation screw in the middle portion of the gliding hole.** Then the condylar neck is reduced. The spongy space of the small fragment is slightly pre-drilled with a twist drill through the guide sleeve in the plate, and a screw inserted

Fig. 13.3 **Fixation is performed by tightening the bone screws in the gliding hole and in the fixation hole of the plate**

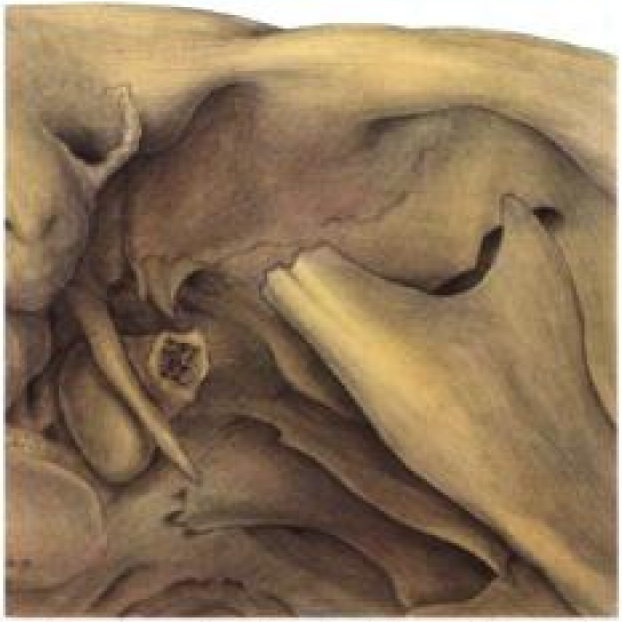


Fig. 13.4 **In severely displaced condylar neck fracture the large fragment is exposed, it is centered, milled and pre-drilled**

(Fig. 13.**4**). Then the lag screw is inserted into the center of the displaced fragment if possible (it is already connected with the plate through the guide sleeve) with a minimum of two turns (Fig. 13.**5**). Utilizing the lever action, the condylar neck is carefully pulled back into the mandibular fossa (Fig. 13.**6**). When the lag screw is placed in the recess that has been milled in the bone, the small fragment should be in its correct anatomical position. Then the plate is pre-fixed in the middle of the gliding hole with a bone screw and, by pulling the plate close, adaptation is achieved between the condyle and large fragment (Fig. 13.**7**). The plate is finally secured by tightening the first bone screw in the gliding hole and with a second bone screw in the posterior fixation hole (Fig. 13.**8**). Slightly varying the direction of the plate in the recess of the large fragment can, in some cases, ensure good adaptation. It must be kept in mind that the bony consistency of the small fragment varies and usually is not very strong. Therefore, care must be taken when tightening the lag screw to avoid producing high torque; surgeons should realize that there may be variance in the subsequent union between the large and small fragment.

Fig. 13.5 **The lag screw is inserted into the center of the displaced fragment (the lag screw is connected with the plate through the guide sleeve) with a minimum of two turns**

Fig. 13.6 **The condylar neck is pulled back in the mandibular fossa**

Fig. 13.7 **The plate is pre-fixed in the middle of the gliding hole with a bone screw and by pulling the plate close adaptation is achieved**

Fig. 13.8 **The plate is fixed by tightening the first bone screw in the gliding hole and with a second bone screw in the posterior fixation hole**

14 Midface Fractures

Klaus Louis Gerlach and Hans-Dieter Pape

Introduction

The aims of treatment of midface fractures are to reestablish midfacial height, width, depth, and projection together with the occlusion and the integrity of the nose and the orbit (Manson, 1986). These requirements can only be achieved by a stable osteosynthesis of the different fractured bones, using, for instance, miniplates and microplates.

Technique

Access via intraoral, paraorbital, or bitemporal incisions allows the use of miniplates or microplates at all levels for the fixation of reduced maxillary fractures. Only some parts of the craniofacial skeleton are constituted of compact and solid bone: the cranium, especially at the level of the superior orbital rims, the zygomatic bone, the orbital margins, the nose and the supporting pillars of the maxillary skeleton including the zygomaticomaxillary buttresses and the piriform aperture (Mariano, 1978). Evaluations of skulls showed that the bone thickness of these regions is strong enough for fixation of plates with 5–7 mm long screws (Ewers, 1977). Therefore in these regions the application of standard miniplates is recommended. However, the role of miniplates in the midface has been superseded by different microplates developed during recent years. These are especially recommended for other anatomical structures whose lamellar structure is only 1–1.5 mm thick. Generally a microplate is used to span comminuted areas from solid bone to solid bone. First, the contoured plate has to be fixed at the solid bone parts, then the various comminuted fragments are repositioned and fixed against the plate by the aid of a small hook or an elevator. A hole is drilled through the plate into the fragment and a screw placed, thereby stabilizing the fragments to the plate. Computerized tomographic (CT) or magnetic resonance imaging (MRI) examinations are often required preoperatively and postoperatively, especially in cases of combined injuries of the cranium and face. It is recommended, therefore, particularly in the midface, that osteosynthesis material made of titanium is used, to avoid distracting artifacts (Hoffmeister and Kreusch, 1991).

Fractures of the Zygoma

For the stable restitution of anatomical form, after repositioning fragments, the application of only one miniplate is recommended, preferably at the frontozygomatic process (Fig. 14.**1**). Alternatively, a plate at the zygomaticomaxilliary buttress may be used. This 'one point fixation' renders a solid stability to the cheek-bone, as demonstrated in large numbers of clinical follow-ups (for instance Michelet, Deymes, and Dessus, 1973; Champy *et al.*, 1977; Iatrou *et al.*, 1991; Krause, Bremerich, and Kreidler, 1991; Zingg *et al.*, 1991).

A further alternative, recommended by Pape (1997), is the use of one or two microplates at the zygomaticomaxillary buttress to stabilize the reduced zygoma.

The frontozygomatic process is approached either by a S-shaped incision below or a straight one within the eyebrow. After exposure of the fracture line at the lateral orbital rim, the reduction is performed by a temporal or oral approach (Gillies, Kilner, and Stone, 1927; Keen, 1909). In German-speaking countries, reduction using a single-pronged bone hook is customary (Stromeyer, 1844). The hook is placed below the body of the zygoma after a stab skin incision; the displaced zygoma is then grasped from below, behind the zygomatic buttress, with the point of the hook and reduced by pulling on the hook until the bone is in place (Figs. 14.**2**, 14.**3**). While the bone fragment is maintained in the correct position by the aid of the hook, the plate is adapted at the bony surface and fixed to the bone. Normally a four-hole plate with four 5 mm or 7 mm long screws is sufficient (see Figs. 14.**1**–14.**3**).

In those cases where stability is questionable, an additional plate may be placed at the zygomaticomaxillary buttress by an intraoral approach. Comminuted fractures of the infraorbital margin have to be reconstructed with a microplate. This is also recommended when a simultaneous orbital exploration is required, but from a mechanical point of view the infraorbital margin offers less additional stability.

Fig. 14.1 **Fractures of the zygoma with inferior displacement**

Fig. 14.2 **Reduction of a fractured and displaced zygoma with a single-pronged bone hook**

Fig. 14.3 **Condition after stabilization of a repositioned cheekbone with a four-hole miniplate osteosynthesis at the lateral orbital rim**

Le Fort I Fractures

Performing a plate osteosynthesis for a Le Fort I fracture requires prior intermaxillary fixation to establish the occlusion (Fig. 14.**4**). Locations for the plates are the zygomaticomaxillary buttress and the lateral margins of the piriform aperture. For this, the surgical approach to the lower portion of the maxilla is exposed through a maxillary degloving or marginal rim incision. Standard four-hole straight plates or L-plates with 5 mm or 7 mm screws are usual. The use of microplates is recommended, especially when the fracture line is near to the root apices. Any additional associated midline separation has to be bridged with a plate at the lower margin of the piriform aperture. The osteosynthesis procedure starts from the stable parts of the midface bones to the unstable ones. The plates must be accurately adapted to the surface of the bone to avoid displacements of the fragments causing disturbances of the occlusion (Fig. 14.**5**).

Le Fort II Fractures

The treatment of central midface fractures starts with the application of arch bars and the reestablishment of the occlusion by means of intermaxillary fixation (Fig. 14.**6**). Surgical approaches are the intraorally degloving incision and, for instance, a subciliar or infraorbital incision to expose the lower infraorbital margin. If a proper reduction cannot be achieved by intermaxillary fixation, the maxilla will need to be mobilized with Rowe impaction forceps. A proper stabilization with plates has to be performed at the zygomaticomaxillary buttress using straight, four-hole, L- or Y-shaped miniplates or microplates. Additional microplates placed at the infraorbital margins allow a secure stabilization of the maxilla without the need for postoperative intermaxillary fixation. Persistent depression of the nose skeleton requires a stabilization of the nasal bones, in some cases. After a coronal incision, or a midline vertical incision from the frontal bone, the detached nasal pyramid fragments have to be reduced and a T-shaped or double Y-shaped microplate has to be adapted accurately to the bony surface. Two screws on the anterior aspect of the frontal bone and one, or two, screws at the nasal bones give a solid support to maintain the anterior projection of the nasal frame (Fig. 14.**7**).

Fig. 14.4 **Dislocated Le Fort I fracture with a triangular bone fragment on the right side after fixation of the occlusion by intermaxillary fixation**

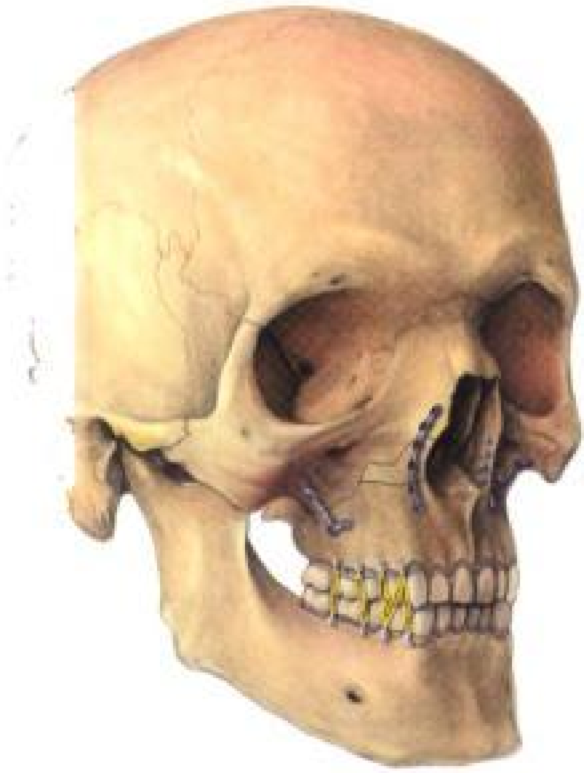


Fig. 14.5 **Reposition of a Le Fort I fracture by means of intermediate intermaxillary fixation and stabilization with a six-hole microplate on the right and a four-hole microplate on the left side at the zygomaticomaxillary buttress and the lateral margins of the piriform aperture**

Fig. 14.6 **Reestablishment of the occlusion by means of intermaxillary fixation**

Fig. 14.7 **Repositioning of a Le Fort II fracture with intermediate intermaxillary fixation and fragment stabilization by means of microplates in typical locations**

Fig. 14.8 **Le Fort III fracture after intermaxillary immobilization and fixation of the zygomatic and nasal bones**

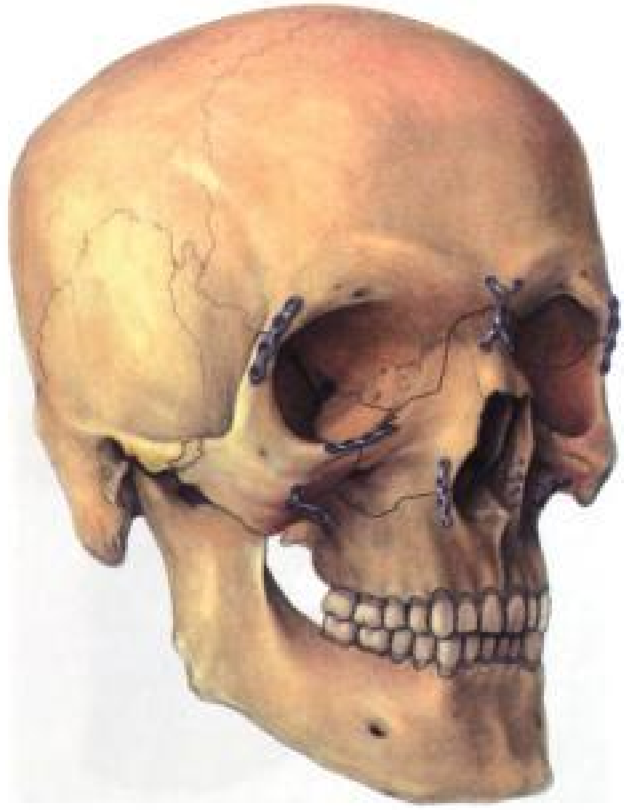


Fig. 14.9 **Stabilization of midface Le Fort III fractures with miniplates and microplates at typical locations, after reduction and intermediate intermaxillary fixation**

Le Fort III Fractures

According to Champy, Lodde, and Wilk (1975), the application of a single miniplate at the frontozygomatic fracture lines after repositioning of the midface offers good stability for treatment of fractures of the Le Fort III type, especially in relatively nondisplaced ones (Champy 1980). However, complete craniofacial disjunctions are very rare. More often, combinations of fractures of the zygomas with Le Fort I fractures are found. In those cases, after fixation of the zygomatic and nasal bones to the skull, any remaining Le Fort I and II fractures have to be stabilized (Fig. 14.**8**). Alternatively, it is sometimes useful to start with the reduction of the central part after reestablishment of the occlusion by intermaxillary fixation. In complex fractures a coronal incision is recommended. After proper reduction, the fragments have to be stabilized at the nasal root, the lateral orbital rims and the zygomatic arches; additional Le Fort I and II fractures are treated as described above (Fig. 14.**9**).

15 Naso-ethmoid Fractures

Peter Ward Booth

Introduction

Naso-ethmoid fractures represent a spectrum of injuries, from simple nasal fractures with undetectable ethmoid involvement, through to grossly comminuted and compounded naso-ethmoid fractures involving the base of skull and significant displacement.

Anatomical Considerations

The tent-like nasal bone is relatively thick, especially in the bridge area, but it is the triangular shape which provides the strength. Further strengthening is given by the 'tent pole' of the vertical bony septum. Thus there is considerable strength against fracture from a direct anterior blow. A blow laterally, however, meets little structural resistance; hence the relative frequency of simple fractured noses that have minimal effect on the ethmoids or the base of skull. Once the nasal 'tent' collapses, forces are dissipated into the air cells, which acts like an air bag. While this mechanically protects the base of the skull, collapse of the naso-ethmoid complex may occur relatively easily if these air cells are large and pneumatized. With minimal force the whole complex may collapse, frequently as one unit, into the frontal sinus. Thus a naso-ethmoid fracture may occur with relatively minimal injuries in some patients. Severe forces, however, may extend the fracture into the base of the skull, frequently seen as a cerebrospinal fluid leak, as the cribriform plate is ruptured.

The medial canthus has a small attachment point to the lacrimal crest. Loss of this attachment leaves an ugly 'blunt' medial canthus further damaged by the inevitable lateral drift. The resultant defect is very unsightly.

The lacrimal apparatus is more frequently damaged by lacerations and more rarely by secondary bony injury. On occasion, damage may be iatrogenic during osteosynthesis stabilization of the fractures.

Clinical Examination

Soft tissue injuries are readily evaluated by clinical examination. Gross swelling may obliterate the canthal attachment but careful exploration normally overcomes this confusion. This exploration should be particularly directed at pulling the canthus to ensure it is still attached to stable bone. If the bone attachment has itself been fractured, lateral displacement of the canthus should be evaluated.

When the lacrimal apparatus is damaged, it is most frequently by direct laceration. However, this is a rare complication. Lacerations in this area must be careful explored. If doubt remains, radiological examination may be indicated.

However, even where swelling is pronounced, careful clinical examination will normally yield a clear understanding of the extent of the fractures. This is important for requesting X-ray examinations that are well 'targeted,' so that maximum information is generated.

Fig. 15.1 **A simple naso-ethmoid fracture illustrating the depression of the soft tissue nasion.** This tilts the nose back producing the 'pig snout' appearance of the nares

Clinically, the naso-ethmoid fractures may present with traumatic telecanthus and impaction of the bridge of the nose, producing a characteristic appearance. The nasal tip is elevated, the bridge depressed and the nares projecting almost horizontally to give the 'pig snout' appearance (Fig. 15.1). The possibility of a cerebrospinal fluid leak should be eliminated.

Markowitz *et al.* (1991) have attempted to classify these bony fractures. This has not provided much useful correlation with outcome, but is frequently used. However, as with any fractures, it is important to determine their severity. Clearly, greater problems occur with compound, comminuted fractures with gross displacement, than with simple fractures (Leipziger and Manson, 1992). In naso-ethmoid trauma, comminution and the actual detachment of the canthus from bone are severe findings and are a poor prognosis for satisfactory outcome.

Radiological Examination

Occipital mental and lateral skull views (at 10° and 45°) are most helpful as an initial screening examination. Computerized tomographic scans are extremely valuable if not, perhaps, even essential. Three-dimensional images are illustrative, but rarely add more additional information than a good conventional computer tomography.

Fig. 15.2 **Skin incisions for exposure of naso-ethmoid fractures.** (after Hans Burkmeir, *Portrait of a gentleman*, ca. 1505/1520, Amsterdam Rijksmuseum)

Treatment

As with any soft tissue injury, treatment consists of:

- examination;
- debridement; and
- closure.

In the case of trauma to the naso-ethmoid area, care must be taken to diagnose any damage to the canthi and lacrimal system as mentioned above. The canthi are rarely detached without damage to the underlying bone. Pure soft tissue injuries to the lids may result in lacrimal system damage. Careful exploration and suturing is required. The vulnerable part is the short medial segment of the canaliculus before it enters the sac, lying between the medial canthi. Fine bore polyethylene or silicone tubes may be inserted into the canaliculus to prevent stenosis.

The principle of hard tissue treatment is simple; reduce the fractures and stabilize (Champy *et al.*, 1978b). In practice, there is significant difference between achieving this in a simple, non comminuted, minimally-displaced fracture, compared with a grossly-comminuted compound 'bag of bones' fracture.

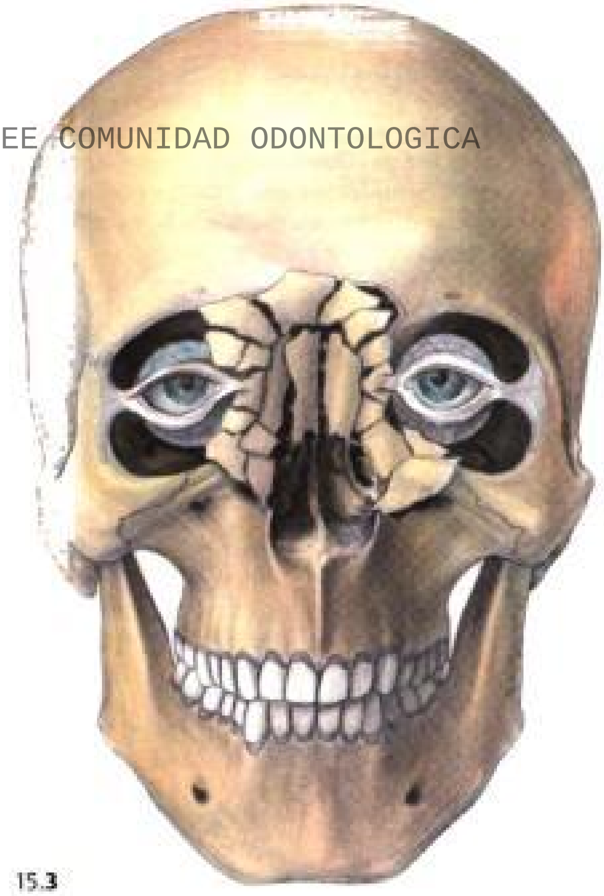
There is however little doubt that, with any fracture, the best results are achieved using the following principles:

- good surgical exposure, either through existing lacerations, or via a coronal flap;
- reduction and stabilization using low-profile, small osteosynthesis plates;
- prompt treatment, as an aid to good reduction;
- immediate bone grafting, if this is indicated.

Surgical Exposure

The potential use of existing lacerations is obvious, but is not without its complications, mainly of infection, as these may be contaminated. Under such circumstances, surgery should be carried out as soon as possible.

There are few skin incisions around the nose and forehead that are satisfactory (Fig. 15.2). This is in marked contrast to the excellent cosmetic results and superior access produced by the coronal flap (Sheperd, Ward Booth, and Moos, 1985). Even with this flap, care must be taken to place it well into the hair line to avoid exposure of the scar should balding occur (see Fig. 3.22). On rare occasions an incision over the nasion is possible (see Fig. 15.2). The coronal incision is combined with subciliary periorbital and upper buccal sulcus incisions as needed. The zygomatic arch is exposed through the coronal incision when necessary (Gruss, 1992).



15.3

15.4

Fig. 15.3 **Naso-ethmoid fracture.** Note that the strong frontonasal buttress is detached superiorly and inferiorly, taking the medial canthal ligament with it

Fig. 15.4 **Microplates in the typical naso-ethmoid injury.** The upper plates are placed across the upper portion of the fractures in the frontonasal region. The lower portions of the microplates are placed in such a way that they are adjacent to the canthal ligament, which is exactly repositioned

Reduction and Stabilization

Microplates will stabilize very small fragments and provide a good three-dimensional stability (Figs. 15.3, 15.4). Particular care must be taken to stabilize any bone that has the canthi attached. In cases of gross comminution it may be helpful to place a plate over the bridge of the nose horizontally, to pull the fragments into a good sharp narrow arch (Figs. 15.5, 15.6).

Fig. 15.5 **Naso-ethmoid fracture showing bony naso-ethmoid-orbital injury in combination with orbital detachment and displacement**

Fig. 15.6 **The plate is being inserted over the fragments to define the nasal form.** Also note the needles being run through the medial canthus from the cutaneous side as identification of detached canthi from the periosteal side is very difficult

Bone Grafting

This is rarely required but in cases of gross comminution an immediate bone graft is indicated. If this is delayed then the soft tissues contract, making later secondary grafting difficult, and possibly leading to erosion through the tight skin. Unfortunately these grossly comminuted fractures are often compound, making a less than ideal environment for immediate grafting.

Detached Canthus

Often when the canthus is described as 'detached' in reality it is attached to a small bone fragment. Under these circumstances with modern microplates it is possible to 'capture' the canthus and reduce it. In true detachment, it is difficult to hold the canthus. The canthus is first located by passing a needle through the canthal angle, easily identified on the cutaneous surface (Fig. 15.6). Once it is located, a fine wire suture is passed through the deep surface of the canthal ligament. This wire is either passed transnasally (Hofmann, 1966; Tessier *et al.*, 1967; Härle and Lange, 1975; Freihofer, 1980) to the opposing canthus, if this is attached, or through a bony point on the other side of the nose. The wire is placed so that it pulls medially and posteriorly.

While this technique is easily described, those experienced in the procedure recognize its shortcomings. The fine wire cuts through the fine canthus very easily, especially if edema puts any significant pressure on the reduction, or if the treatment is forced to be delayed. For this reason it may be helpful to support the canthal reattachment from the cutaneous surface. This can be carried out using a preformed clear acrylic button (Fig. 15.7). The risk of this procedure is skin necrosis, but with clear acrylic the status of the skin can be monitored.

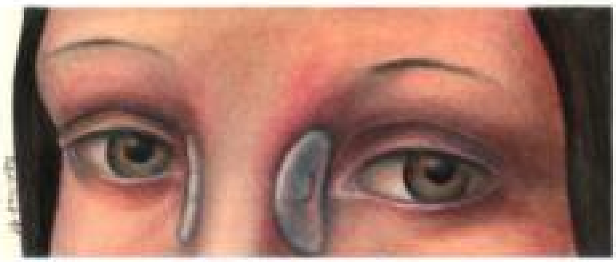


Fig. 15.7 **Clear acrylic buttons can usefully support those rare cases of total canthal detachment.** In late-treated cases, the transnasal wire used alone frequently cuts through the delicate canthal tendon if there is any tension. (after Giovanni Antonio Boltraffio, *Portrait of a lady as St. Lucy*, ca. 1500, Foundation Museum Thyssen Bornemisza, Madrid)

16 Panfacial Fractures: Planning an Organized Treatment

Rudolf R.M. Bos

Introduction

In the treatment of panfacial fractures all treatment modalities for single fractures of the craniomaxillofacial area, described in other chapters, come together. A successful outcome of panfacial fracture treatment, however, demands a systematic approach by an experienced team of specialists, working in a trauma center that has all facilities for proper patient care. Developments during the last quarter of the 20th Century (such as computerized tomography, wide open reduction, internal fixation, immediate bone grafting and soft tissue handling) have revolutionized the potential for restoring the pre-injury appearance and function of panfacial fracture patients. The keys to successful treatment of panfacial trauma remain good exposure, careful reduction, and fixation of the fractures.

The craniofacial skeleton consists of 22 different bones. These bones surround the different cavities that together form the head. These cavities are the cranium, the orbits, the sinuses, the nose and the mouth. In the craniofacial skeleton, thicker portions of bone are connected to thinner bony walls. These thicker bony structures are called 'buttresses' and maintain the craniofacial proportions in height, width and anterior-posterior projection (Figs. 16.**1**, 1.**8**).

The buttresses form the key to the reconstruction of panfacial fractures and were originally described by Sicher and Tandler (1928), then Merville (1974) and later expanded by Gruss and Mackinnon (1986).

Wide exposure of fractures was also advanced by Merville (1974) using the principles of craniofacial surgery transferred to fracture repair. Exposure of the buttresses allows alignment and fixation of the fractures and so provides the potential for anatomic reduction of the bones. Internal fixation with combinations of different sizes of plates and screws provides three-dimensional stability and makes postoperative intermaxillary fixation almost superfluous. (In Fig. 16.**4** a guide for the use of different plate-screw osteosynthesis systems in the craniofacial area is given).

Highly comminuted bones are replaced by bone grafts. Bone grafting is also used to supplement missing bone or bone volume. However, the need for primary bone grafting is largely reduced because of the stability provided by plate and screw fixation. It is still unclear how long plate-screw fixation provides stability when bridging an area of bone loss. In case of substantial bone loss or gross comminution bone grafting may still be necessary to guarantee long-term stability (Klotch and Gilliland, 1987).

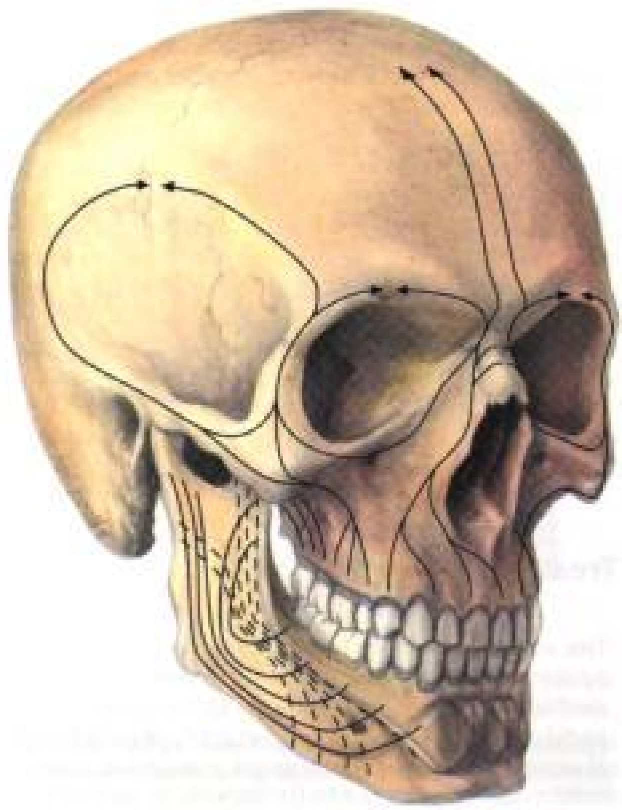


Fig. 16.1 **The different buttresses, marked by arrows, that determine the width, height and projection of the head.** These buttresses form the key to the reconstruction of panfacial fractures (see Fig. 1.**8**) Biting forces produce tension forces (dashed lines) at the upper border and compressive forces (solid line) at the lower border of the mandible. Torsion forces are produced anterior to the canines of the mandible

Diagnosis

In this specific sequence a careful history, physical examination and radiographic evaluation are essential to get a proper understanding of a panfacial injury complex. Whenever possible, information should be gathered about the pre-injury appearance, occlusion and function. Photographs and dental records can be very helpful.

Physical examination should consist of static and dynamic inspection and palpation from chin to crown, to identify injuries of the soft tissue, bone and neurovascular bundles.

Special attention should be given to the naso-ethmoid region, the palate, the eye and the condylar process, where injuries are easily overlooked. All patients with severe craniofacial trauma deserve a complete ophthalmologic evaluation.

Computerized tomographic scanning has replaced most conventional plain radiographs except for those that image the ascending ramus of the mandible, including the condylar process. For initial evaluation, plain radiographs like the Waters view in combination with a submentovertex view and a left and right half mandibular view, described by Eisler, provide valuable overall information. Detailed computerized tomographic scanning in axial planes provides important information concerning the extent of craniomaxillofacial injuries. Two-dimensional coronal and sagittal reconstructions are most valuable for evaluation of fractures of the orbital walls, maxillary buttresses, and mandibular ascending ramus. The role of three-dimensional imaging is inconclusive. One has to be cautious in evaluating three-dimensional images in areas where the bone is thin or where there is minimal or no displacement. False positive as well as false negative findings are possible. As technology advances, three-dimensional imaging may become of more importance (Fig. 16.**2**).

Currently, magnetic resonance imaging seems of little importance in the initial assessment of a panfacial trauma patient.

Fig. 16.**2** **Panfacial fracture**

Treatment Planning

Plate and screw fixation has significantly influenced the sequence of panfacial fracture treatment. It makes it possible to fully reconstruct the mandible including subcondylar fractures, which is important to preserve vertical mandibular height. By complete mandibular internal fixation the craniomandibular relation is restored, so turning a panfacial fracture into an isolated midface fracture. However, this implies that one has to perform an open reduction and internal fixation of subcondylar fractures which is not favored by many surgeons because of the anatomical hazards and the difficulty encountered during this operation. It is also a time-consuming procedure. On the other hand, one should realize that unilateral and, even more so, bilateral condylar neck fractures are looked upon more and more as an absolute indication for open reduction and fixation when part of a panfacial fracture. To prevent shortening of the vertical height of the face, due to telescoping of bone fragments and loss of anteroposterior dimension, fixation of the condylar fractures is essential. One also should think of the potential for further displacement of initially undisplaced or dislocated condylar fractures during the process of fracture reduction (Zide and Kent, 1983; Hayward and Scott, 1993).

Plate and screw fixation also creates a stable base in the midface. So, instead of starting with complete restoration of the mandible, internal fixation of the midface with plates and screws is performed to offer a stable and anatomically correct base for subsequent mandibular fracture treatment (Merville, 1974; Gruss and Mackinnon, 1986). The advantage of this sequence is that one can possibly omit open treatment of subcondylar fractures. A prerequisite of such a sequence is that there are enough bony landmarks available to allow anatomical reduction of the midface, including the maxilla. Gruss and Mackinnon (1986) advocated the need of always first reconstructing the so called 'outer facial frame' in panfacial fractures. This should start at the root of the zygomatic arch, advancing to the malar complex and the frontal bar, followed by 'the inner facial frame' or naso-orbito-ethmoidal complex, when necessary using bone grafts to reconstruct orbital walls (Fig. 16.**3**). Then the maxilla is fixed by plate and screw fixation along the buttresses at the Le Fort I level, when necessary using bone grafts (Gruss and Mackinnon, 1986). Eventually intermaxillary fixation is performed to put the mandible in its normal position, after which mandibular fractures are fixed by plates and screws. Fractures of the condylar process can be treated closed using this sequence (Fig. 16.**4**).

Kelly *et al.* (1990) and Manson *et al.* (1995) proposed complete reduction and fixation of the mandible, including fractures of the condylar process, as the base for proper intermaxillary fixation. If there is a sagittal fracture of the maxilla, this is reduced and fixed to reestablish the pre-injured maxillary arch that is necessary to establish the correct position for the mandible using intermaxillary fixation (Figs. 16.**5**, 16.**6**).

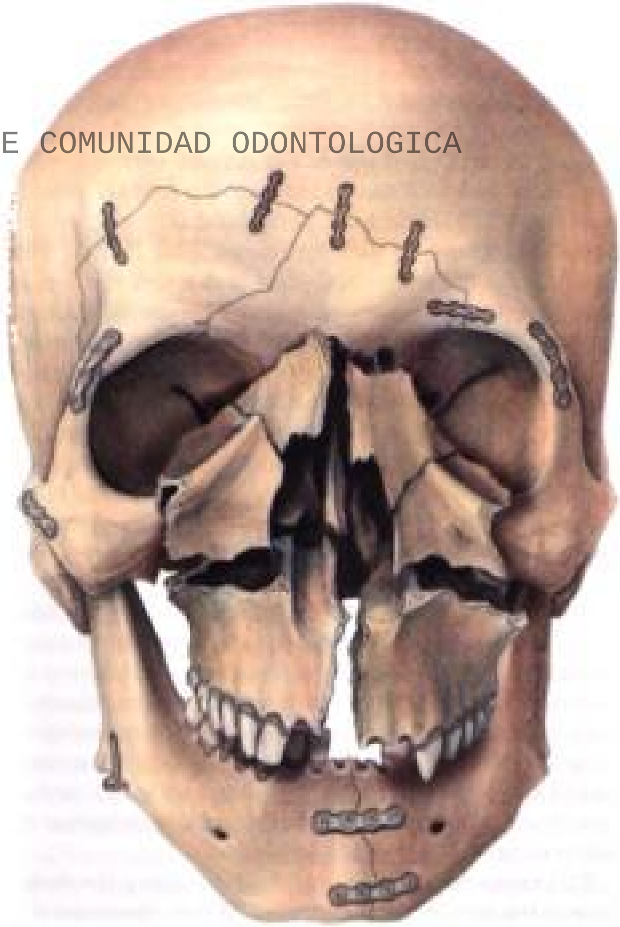


Fig. 16.3 **The sequence of treatment of the fracture should start in that area that gives maximum information and certain anatomical reduction.** In this example the mandible and zygoma have been reconstructed first and serve as a frame for the maxilla

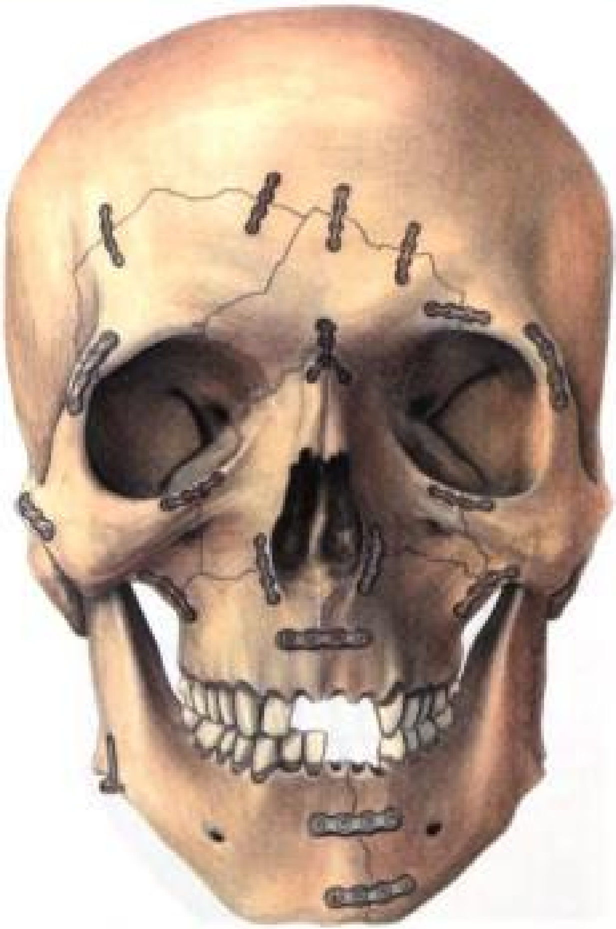


Fig. 16.4 **When mandible and zygoma are reconstructed the maxilla can be set up like a key in a lock.** Complete reduction and internal fixation of a panfacial fracture using different types of plates and screws. Main frame for the use of different plate–screw osteosynthesis systems in the craniofacial area: cranial vault: micro-systems; midface: micro-systems; lateral orbital rim: from micro-systems to mini-systems; mandible: from mini-systems to reconstruction systems

Fig. 16.5 **Internal fixation of sagittal fractures of the maxilla is performed using microplates over the fracture in the palatal vault, combined with a microplate over the fracture in the front of the maxilla above the level of the apices.** Arch bars are placed to allow intermaxillary fixation

Fig. 16.6 **Sagittal fracture of the maxilla is repositioned and fixed by microplates**

Fig. 16.7 **Regions that more often demand reconstruction with bone grafts in panfacial fractures: frontal sinus wall, orbital walls, dorsum of the nose, malar complex and maxillary sinus walls.** The use of split calvarial bone is preferred

After reconstruction of the mandibulomaxillary block, the cranial vault is reconstructed including the forehead. Then the naso-ethmoid complex is reduced and fixed to the forehead in the region of the glabella. Subsequently the outer facial frame is reconstructed starting at the dorsal root of the zygomatic arch and advancing to the lateral orbital and intra-orbital rims (see Fig. 16.**3**). Final correction at the Le Fort I level is performed with plates and screws over the buttresses (see Figs. 16.**4**–16.**6**), when necessary using bone grafts. Bone grafts are used for reconstruction of the orbital walls and the nose (Fig. 16.**7**).

There is no consensus as to which sequence in the management of panfacial fractures is the best. It becomes more and more obvious that factors like fracture displacement and amount of comminution are important for determining the choice. However, one thing is clear; the decision for one or another sequence should be based on a careful diagnosis.

Complete exposure of panfacial fractures is the essential first step in treatment by internal fixation. The need for different incisions is dependent on the treatment plan based on a careful diagnosis. The entire facial area can be exposed and reconstructed using a combination of coronal incision, one of the different lower eyelid incisions, the mandibular and maxillary gingivobuccal sulcus and a preauricular, retromandibular or submandibular incision.

With the increased use of the coronal incision, other local facial incisions can be omitted. If a coronal incision is not used, different local periorbital incisions are required. Exposure of the zygomatic arch is not then possible. For reduction and plate and screw fixation of the outer facial frame and cranial vault, a coronal incision is a prerequisite. The coronal incision gives a wide exposure of the cranium and upper craniofacial skeleton. It gives the surgeon the optimal access for proper reduction and fixation of fractures and to a useful site for bone grafting, so avoiding another donor site. Simple fractures can be reduced and fixed through local incisions, while complex fractures demand wider exposure through a coronal incision. The use of traumatic lacerations may also be helpful.

The majority of patients with panfacial fractures have other injuries. Most of them are candidates for immediate surgery. There are only a few contraindications for immediate surgical intervention, such as cardiopulmonary instability, coagulopathy, and severe neurological trauma with high intracranial pressures. Delayed surgery causes scarring to develop, impeding anatomical reduction of the fractures. Therefore immediate definitive repair within 48–72 hours is advocated.

If there are no contraindications for surgery, the multisystem injuries are normally treated first. However, it is important not to neglect control of bleeding, first from existing intraoral or extraoral lacerations, by cautery, suturing or temporary tamponade. Before closing a laceration, it is important to determine whether reduction and fixation of an underlying fracture could be performed through that laceration.

Special attention should be given to the patient's pre-surgical and post-surgical airway. In cases of panfacial fractures, a tracheotomy is preferred. It not only provides an adequate peri- and postoperative airway, but also allows the surgeon optimal access to the craniomaxillofacial regions. However, if no indication for tracheotomy exists other than surgical convenience, the submental route for endotracheal intubation can be easily used (Altemir, 1986).

At the end of what is normally a long operation to reduce and fix panfacial fractures, proper handling of the soft tissue incisions and lacerations deserves attention. To prevent 'sag' of the facial soft tissues careful management of the subcutaneous layers is necessary, closing periosteal incisions at specific points of the skeleton. The coronal incision is closed in at least two layers (galea and scalp). Closure of the periosteum over the zygomaticofrontal suture, at the lateral canthal ligament area and at the infraorbital rim, is necessary to reposition the soft tissue at its proper location on the underlying skeleton. A layered closure (muscle and mucosa) of the gingivobuccal sulcus incision is performed. Careful closure of the skin in layers provides less risk for visible scars, as it prevents widening of the scar.

Special attention should be given to difficult reattachment of the medial canthal ligament using microplates or transnasal wires (Figs. 15.4, 15.6, 15.7) to prevent very unesthetic traumatic telecanthus (Markowitz *et al.*, 1991).

Conclusion

A planned sequence of surgery, based on a careful diagnosis, enables the surgeon to restore the appearance and function of patients in even the severest cases of panfacial fractures. The surgeon must choose the sequence of treatment for each individual case, based on detailed clinical and radiographical diagnosis in which fracture displacement and amount of comminution are especially important factors.

To ensure a precise anatomical reduction, reconstruction should be started in the area that gives maximum information. Fixation of fractures with different plates and screws is nowadays state of the art, providing excellent three-dimensional stability and quick recovery to normal function.

Wide exposure, using the buttresses, and the immediate use of bone grafts when necessary, are important ingredients for a successful outcome. Careful management of lacerations and incisions is necessary for an esthetic and functional result. Immediate definitive repair within 48–72 hours is advocated to prevent scarring, which impedes anatomical reduction of the fractures. Information on the exact surgical techniques for treatment of different types of fractures is given in the relevant chapters.

17 Osteotomies of the Mandible

Paul J. W. Stoelinga

Sagittal Split Osteotomy

Introduction

The sagittal split osteotomy described by Obwegeser (Trauner and Obwegeser, 1957) is probably the most frequently used osteotomy to correct mandibular anomalies including hypoplasia, hyperplasia, and asymmetries. Miniplates can be used to stabilize these osteotomies allowing for early release or even no intermaxillary fixation. Studies have proven that the stability achieved, at least in advancement cases, is adequate and highly predictable (Scheerlinck *et al.*, 1994). The advantages of using plates as compared with positional or lag screws can be summarized as follows:

- plates can be bent to adapt to the anatomical situation caused by the positional changes of the fragments; excessive, unwanted torquing, particularly of the proximal fragments, can thus be avoided;
- extraoral stab incisions are not necessary when using miniplate fixation;
- damage to the inferior alveolar nerve can be minimized because the nerve cannot be injured by the screws; since the fragments are not pulled together by screws, the nerve cannot be damaged by compression either;
- if, after the patient is awake and sitting up in a natural position, the occlusion is found to be inadequate because of a changed position of the distal fragment, the plates may be adjusted without a further general anesthetic. The procedure can be done under local anesthesia several days after the first operation, when the swelling has subsided. Adjustment usually only includes repositioning of the screws in the distal fragment, after fine adjustment of the occlusion with temporary intermaxillary fixation.

Disadvantages include:

- the bone cuts have to be brought relatively further forward to allow for easy application of the plates; this may increase the risk of buccal plate fractures (bad splits);
- ischemic necrosis of parts of the buccal plate around the screws is sometimes seen. This gives rise to an inflammatory reaction but does not usually interfere with overall bone healing.

Technique

The sagittal split osteotomy (Trauner and Obwegeser, 1957) is carried out using the modifications of Dal-Pont (1961), Hunsuck (1968) and Epker (1977). The anterior vertical cut is situated approximately between the first and the second molar. Following placement of an acrylic splint and intermaxillary fixation, the proximal fragment has to be positioned with a gauze-packing instrument. In cases of setback of the distal fragment, the appropriate amount of bone to be cut from the proximal segment can now be calculated (Fig. 17.1). An appropriate miniplate is selected, long enough to include two holes in the proximal and distal segment. The plate is bent to lie passively against the bone fragments. A straight Kocher clamp is then applied to the proximal segment and the segment is rotated anteriorly and superiorly. A hole in the proximal

Fig. 17.1 **Buccal cortical fragment to be removed to allow mandible to be set back**

Fig. 17.2 **The first screw is inserted.** At this stage the proximal fragment may be put into its proper position, to check plate alignment

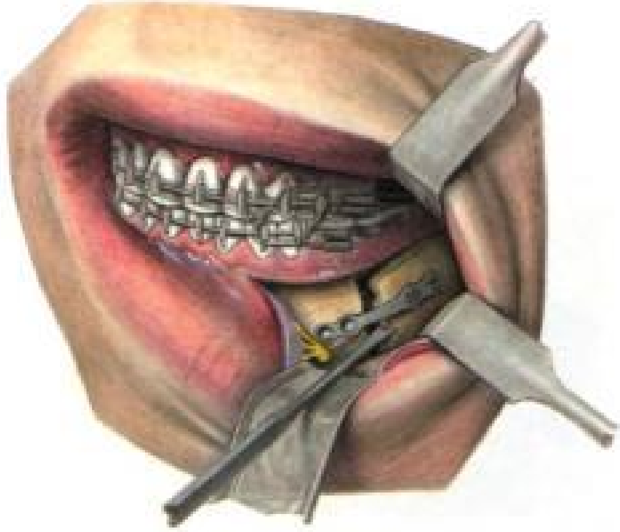


Fig. 17.3 **A gauze-packing instrument is used to hold the proximal fragment in position while screws are inserted in the distal fragment**

segment is drilled and the plate screwed in position using a 5 mm or 7 mm screw (Fig. 17.2). Plate position may now be checked and adjustments can be made. Following this, a second hole is made while the proximal fragment is again pulled forward and slightly rotated upwards. The second screw is then placed and tightened. The gauze-packing instrument is then used to push the proximal fragment into its proper position, taking care to correctly align the lower margin in relation to the distal segment (Fig. 17.3). Holes are drilled in the distal segment and screws placed and tightened (Fig. 17.4). A similar procedure is carried out on the other side, after which the intermaxillary fixation is released. The occlusion can now be checked by manually manipulating the chin with the condyles seated in their fossae. If an error is noted intermaxillary fixation can be reapplied and the plates readjusted, which involves repositioning the distal screws only.

Fig. 17.4 **The screws have been inserted in the proximal fragment and the distal fragment is in place**

Fig. 17.5 **Osteotomy design for advancement of the mandible**

Fig. 17.6 **A six-hole plate or a four-hole plate with a bridge is used to fix the fragments**

Fig. 17.7 **A four-hole plate, used to fix an inadvertently fractured buccal fragment**

In class II cases the osteotomy is carried out using the same technique as in class III patients. After osteotomy the mandible is positioned forward and the cortical bone gap is bridged with a four-hole or six-hole miniplate (Figs. 17.**5**, 17.**6**).

If the buccal plate is inadvertently fractured while splitting the mandible (bad split), the loose fragment can be fixed to the proximal fragment using a miniplate. In these circumstances it is best to complete the splitting first. The proximal fragment can then be mobilized and pulled forward to allow the miniplate to be fixed (Fig. 17.**7**). The fixed fragment can thus be used for fixation of the osteotomy site, but clearly this type of fixation cannot be described as rigid. A period of intermaxillary fixation of at least 4 weeks is recommended for such patients.

Vertical Ramus Osteotomy

Introduction

The vertical ramus osteotomy has frequently been used in the past for the correction of mandibular hyperplasia (Robinson, 1956). The application of an intraoral vertical ramus osteotomy, however, almost precludes the use of rigid fixation, including miniplates, because of lack of access and the risk of damage to the inferior alveolar nerve.

This osteotomy, however, is still the best option if vertical movements of the ascending ramus are needed, or in cases where extreme rotations of the distal fragments are anticipated. This may occur in patients with facial asymmetries. Lengthening or shortening of the ascending ramus, using the vertical ramus osteotomy, can only be done through an extraoral route (extraoral vertical ramus osteotomy). Proper access to the fragments enables the surgeon to reduce the amount of bone needed (Fig. 17.8), or to position the proximal fragment with the condyle properly seated in the fossa. It also allows for the application of miniplates under controlled conditions.

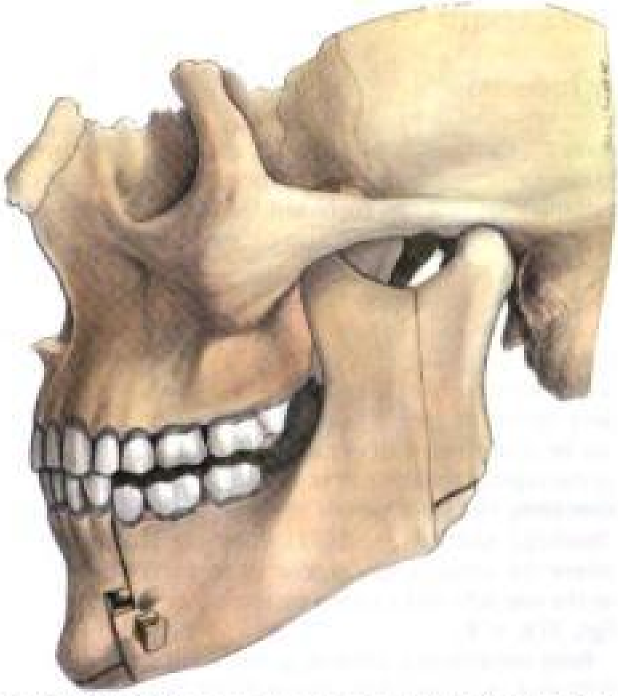


Fig. 17.8 **Simultaneous osteotomies of the horizontal body and vertical ramus allow for cranial positioning of the premolar- and molar-bearing area of the mandible, in cases of posterior vertical open bite.** Excess bone can be removed as indicated

Technique

Access is gained through a submandibular incision. Careful dissection, to avoid damage to the mandibular branch of the facial nerve, should expose the lateral aspect of the ascending ramus, up to the sigmoid notch. A vertical bone cut is made from the sigmoid notch to the angle of the mandible, its design depending on the preference of the surgeon. Care should be taken to avoid damage to the inferior alveolar nerve. The proximal fragment can be positioned with a gauze-packing instrument or forceps, after repositioning the distal fragment, placing the acrylic wafer and intermaxillary fixation.

A miniplate of appropriate design and length is bent to accommodate the anatomic contour and fixed with 5 mm or 7 mm screws (Fig. 17.9). L-plates are found to be extremely useful for this purpose. If needed, and if the anatomy allows, a second plate may be placed above the first. The surgeon, however, should be aware of the location of the inferior alveolar nerve near its entrance into the mandible. The buccal plate may be thin which can give rise to damage to the nerve when screws enter the bony canal.

In this author's experience, one plate will suffice if only one side is treated in this way and the other side is treated with a sagittal split osteotomy, using the usual one plate fixation.

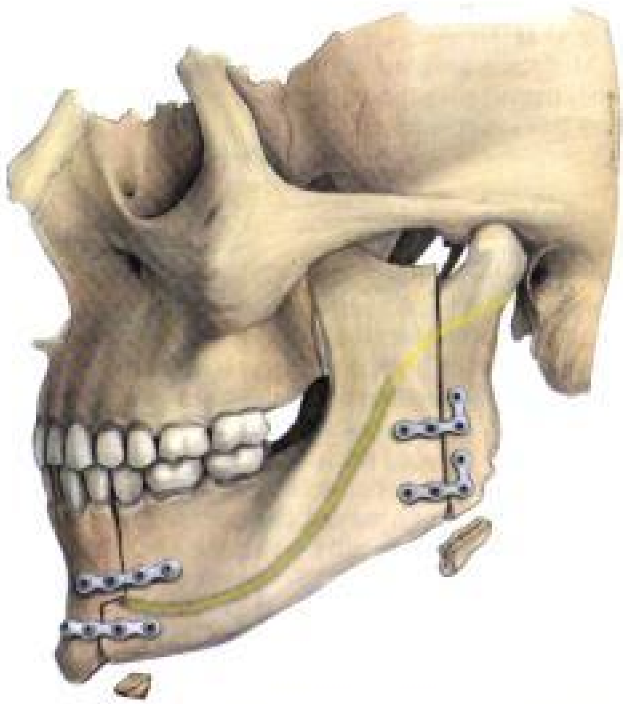


Fig. 17.9 **Intermediate fragment positioned and fixed with appropriate miniplates**

Body (Step) Osteotomies

Introduction

Body osteotomies or ostectomies are particularly useful in cases where asymmetries in the horizontal part of the mandible need to be corrected (Sandor, Stoelinga, and Tideman, 1982). They can also be used for patients who have teeth missing from the mandibular arch, thereby avoiding or minimizing the need for bridges, if setback osteotomies are carried out. The best indications, however, are those cases in which the occlusal plane needs to be corrected, because of reversed or extremely deep curves of Spee. In special cases, body osteotomies can be combined with vertical ramus osteotomies, such as the sagittal split osteotomy or intraoral vertical ramus osteotomy and extraoral vertical ramus osteotomy (Stoelinga and Leenen, 1992). They are also indicated where the surgeon may choose to do a body osteotomy on the one side and a ramus osteotomy on the other (see Figs. 17.**8**, 17.**9**).

Body ostectomies anterior to the mental foramen are indicated in some edentulous patients with a reversed intermaxillary relationship caused by a combination of advanced alveolar resorption and a preexisting hyperplastic mandibular body. A body ostectomy allows for correction of the anterior and transverse dimensions of the mandible in a controlled fashion. The mandible can be set back by taking out a planned amount of bone, while at the same time the transverse dimension can be reduced by inward rotation of the proximal fragments (Fig. 17.**10**).

Miniplates are ideal to fix the fragments rigidly in all body osteotomies, thus avoiding the need for intermaxillary fixation or splints.

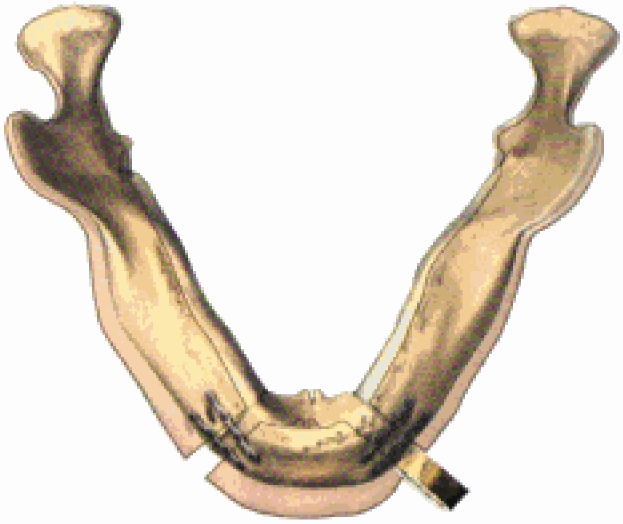


Fig. 17.**10** **Excision of a calculated amount of bone in the horizontal body allows for narrowing of the mandibular arch and relative setback of the chin**

Technique

The area where the osteotomy has to be carried out is exposed through a mucoperiosteal incision and dissection. The design of the incision is largely defined by the anatomical situation, such as the presence of teeth. The mucoperiosteal dissection should also be carried out on the lingual side to the level of the horizontal cut of the osteotomy. A stepped cut is made in the bone, avoiding damage to the inferior alveolar nerve. Where setback of the distal fragment is needed, the appropriate amount of bone is removed first, after which the horizontal bone cut is completed (Fig. 17.**11**). Following reposition of the distal and proximal fragments, the occlusion is secured using an acrylic splint and intermaxillary fixation.

A plate of appropriate length to include two holes in the proximal and distal segment is selected and bent to fit the step in the bone contour. The plate is fixed with four screws of 5 mm or 7 mm length, below the mental foramen and mandibular canal (Fig. 17.**12**).

If the height of the mandible permits, a second plate is used and fixed above the level of the nerve. Care should be taken not to damage the apices of neighboring teeth. In those cases where application of a plate above the nerve is not possible, an arch bar should be used or an acrylic splint fixed to the lower teeth.

In body osteotomies in edentulous patients, there is no problem in using two plates on either side (see Fig. 17.**10**). However, attention should be paid to the course of the mandibular canal so as to avoid penetrating it with the screws, which could cause nerve injury.

Anterior Subapical Segmental Osteotomy

Introduction

This osteotomy, first introduced by Hofer (1942), is particularly suitable for correcting supraposition of the lower anterior teeth, but can also be used for advancement or setback in selected cases (Fig. 17.**13**). In most cases this osteotomy is carried out in conjunction with ramus osteotomies to correct more complicated mandibular deformities. Stabilization of the anterior fragment is easily accomplished with miniplates, since muscular displacing forces tend to be minimal.

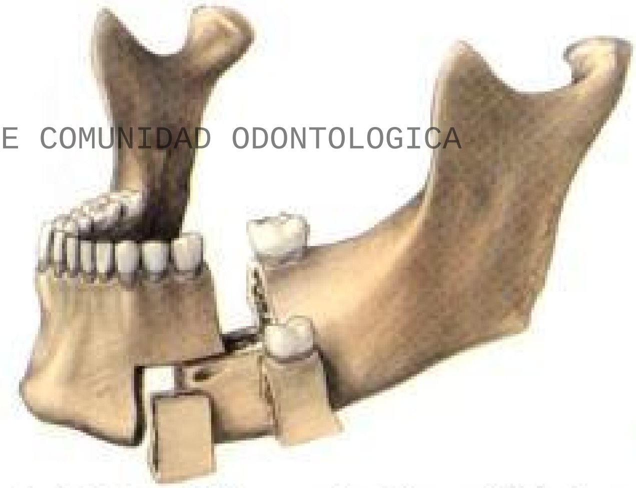


Fig. 17.11 **Bone blocks removed to allow mandible to be set back**

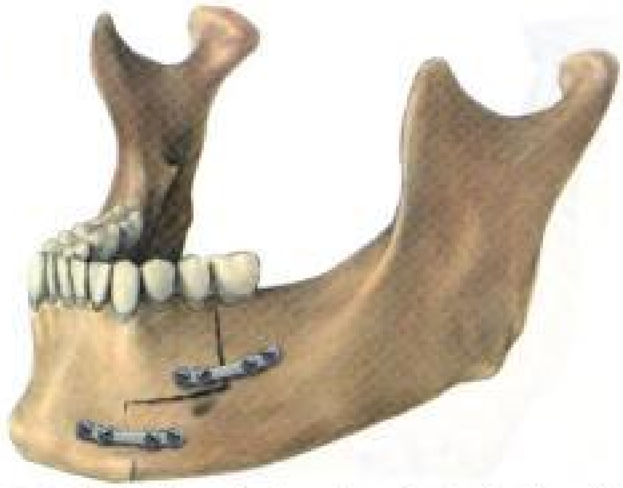


Fig. 17.12 **Miniplate fixation using a four-hole plate with bridges**

Fig. 17.13 **Anterior subapical segmental osteotomy (according to Hofer) to correct supraposition of the lower anterior teeth**

Fig. 17.14 **Anterior subapical segmental osteotomy.** Two four-hole plates, positioned vertically

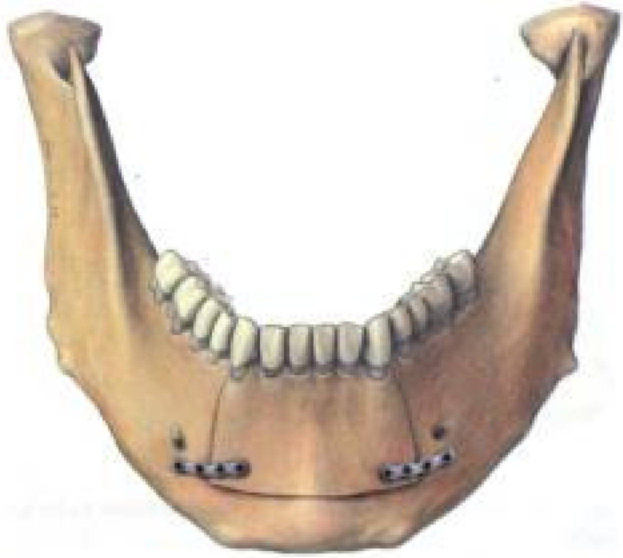


Fig. 17.15 **Anterior subapical segmental osteotomy.** Two four-hole plates, horizontally placed

Technique

Following completion of the osteotomy, which is carried out in the usual fashion, the fragment is maneuvered into place and temporarily secured with the aid of an acrylic splint. Intermaxillary fixation may be used at this stage if necessary.

Two four-hole plates of any configuration may be used to stabilize the fragment, if placed in a vertical fashion (Fig. 17.**14**). This, however, may not be feasible because of the presence of the roots of the anterior teeth. The plates may then be placed horizontally (Fig. 17.**15**) but this may cause the fragment to tilt. This can be counteracted, however, by a rigid orthodontic wire inserted postoperatively.

Genioplasties and Midline Symphyseal Osteotomies

Introduction

Genioplasties are widely used to correct chin abnormalities (Trauner and Obwegeser, 1957). Depending on the design of the osteotomy, the osseous chin can be moved in any direction and usually adequately fixed with wire osteosynthesis. Miniplates, however, can be extremely useful when augmentation is wanted in a vertical dimension, or when extreme advancement is anticipated. In general, an unstable symphyseal bone fragment can be adequately fixed with two miniplates.

Midline symphyseal osteotomies are sometimes carried out to narrow or widen the lower dental arch. This, almost inevitably, has to be combined with bilateral ramus osteotomies to allow for these movements (Fig. 17.**18**). Narrowing of the mandible is fairly easy to achieve, since no muscle stretching is involved. A narrowing of up to 5 mm in the molar area is feasible, without too much tilting of the mandibular body. Widening of the mandible is much more difficult since it involves stretching of the mylohyoid muscle. If anterior widening is wanted, bone grafting is necessary to bridge the gaps. This procedure carries a considerable risk of periodontal damage and should only be considered in cases of extremely narrow mandibles, or when anterior teeth are missing.

In both circumstances miniplates are highly reliable in that adequate fixation can be achieved, allowing for immediate release of intermaxillary fixation.

Technique

In genioplasties the fragment is held in place with bone clamps or forceps and two four-hole plates of suitable length are selected to include two holes in the chinbone fragment and in the body of the mandible. The best position is vertical (see Fig. 17.**16**) but, if anatomical circumstances preclude such position, the plates may be placed in any other suitable direction and area, since displacing muscle forces are minimal.

The plates are bent to adapt to the anatomical situation and screws of 5 mm or 7 mm are used to fix the chin fragment. Existing gaps may be filled with either autogenous bone grafts or with allogenic material (see Fig. 17.**17**).

Midline osteotomies are best treated with two four-hole plates, according to Champy's principles for treating symphyseal fractures. For this reason the proximal fragment is loosely fixed in intermaxillary fixation before the actual midline splitting is done. The bone cut is first made through the buccal cortical bone, between the roots of the central incisors. Below the level of the apices, the cut should also include the lingual cortex of the symphyseal body. Following insertion of an acrylic splint and

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18 Osteotomies of the Maxilla

Paul J. W. Stoelinga

Anterior Maxillary Segmental Osteotomy

Introduction

The anterior maxillary segmental osteotomy described by Wassmund (1935a) and Wunderer (1962) was one of the most frequently used osteotomies to set back the anterior segment of the maxilla in cases of dentoalveolar protrusion. With the increased cooperation between orthodontists and surgeons, the need for these osteotomies has been drastically reduced. Yet, there are still indications for performing an anterior maxillary segmental osteotomy, particularly when vertical movements are required or when asymmetries need to be corrected. Miniplates may play an important role in stabilizing the anterior segment.

Technique

Both the Wassmund and Wunderer approaches include a distally curved but basically vertical incision in the buccal vestibule. This usually provides sufficient access to apply a four-hole plate on each side to stabilize the fragment. Attention should be paid to the location of the root tips of canine and bicuspids in order not to make burr holes in these roots. There is usually room for one plate on each side, which provides enough stability, particularly when an acrylic splint is wired in place (Fig. 18.1).

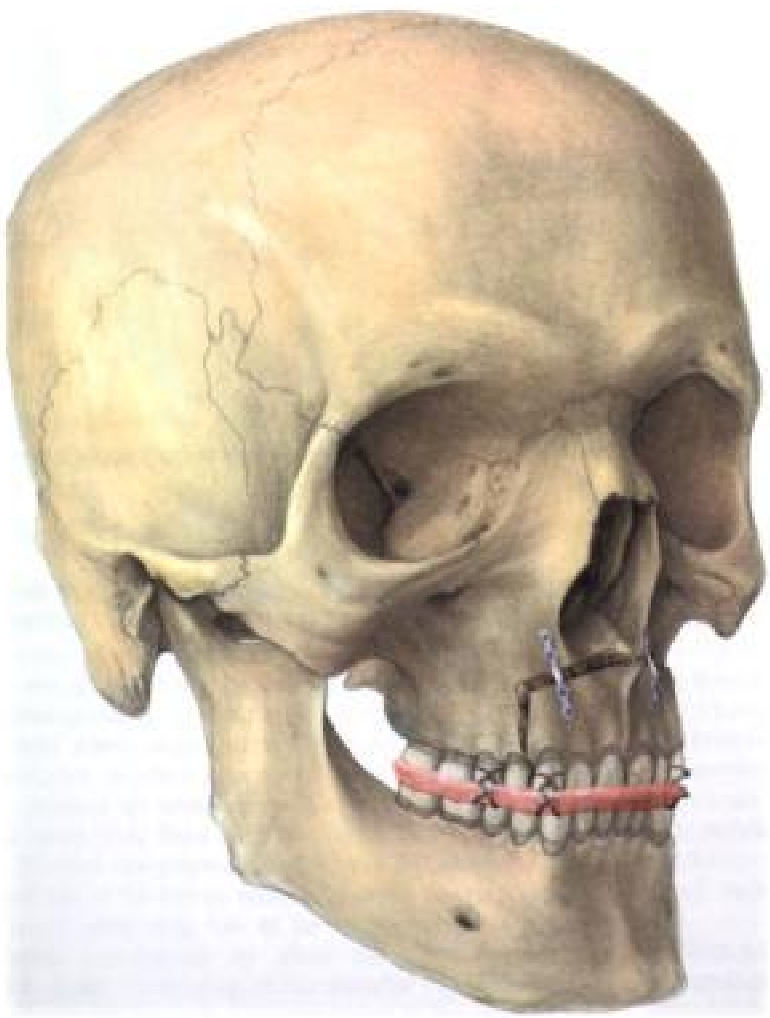

Fig. 18.1 **Anterior segment secured by two four-hole plates and an acrylic splint wired to the maxillary teeth**

Posterior Maxillary Segmental Osteotomy

Introduction

The bilateral posterior maxillary segmental osteotomy, introduced by West and Epker (1972), to close anterior skeletal open bite is rarely used anymore because tilting osteotomies on a Le Fort I level have largely replaced this technique. The posterior maxillary segmental osteotomy, however, has several other indications. It may be used to close gaps in the alveolar process when teeth are missing, or to correct asymmetries in the arch form in any direction.
The technique is most useful, however, when the lesser fragment in patients with cleft lip and palate needs to be repositioned. Miniplates, but especially microplates are almost indispensable for stabilizing the fragment.

Technique

The technique most commonly used entails a buccal mucoperiosteal pedicle as the main blood supply to the fragment. This implies that a relatively small vertical incision can be made which, of course, limits the access. After completion of the osteotomy through a palatal incision, the fragment is maneuvered into place and fixed to the main fragment using an acrylic splint. A suitable four-hole microplate is selected, which may be straight or L-shaped. In most cases only one microplate can be placed, fixed with 4 mm or 6 mm screws. Defects resulting from positional changes of the segment should be grafted, preferably using autogenous bone. One plate does not provide enough stability but in combination with an orthodontic arch wire or acrylic splint, or both, stability is usually adequate (Fig. 18.2).

Fig. 18.2 **Posterior segment secured with one four-hole microplate and an acrylic splint wired to the maxillary teeth**

The plates can best be fixed at the zygomatic buttress and alongside the piriform aperture, since the bone in these locations is usually thicker than in the canine fossa. Miniplates or microplates are bent to follow the curvature of the bone structures or to accommodate discrepancies that may exist in a transverse or anteroposterior plane. Two straight four-hole or L-shaped plates on each side are usually sufficient to adequately stabilize the maxilla (Fig. 18.**3**). An additional plate, placed horizontally under the piriform aperture, may be necessary in the case of midline splits to adjust for transverse discrepancies. This plate can be bent under the nasal spine (Fig. 18.**4**). The same applies when simultaneous segmental osteotomies are carried out in the bicuspid-molar area.

Bone grafts should be used when defects are apparent after repositioning of the fragment. This is particularly important when the maxilla is moved downwards. The blocks are contoured to fit the gaps in the lateral sinus wall and preferably placed with their cortex towards the plates (Fig. 18.**5**). If necessary, a screw may be inserted in the free bone graft to help to stabilize the graft.

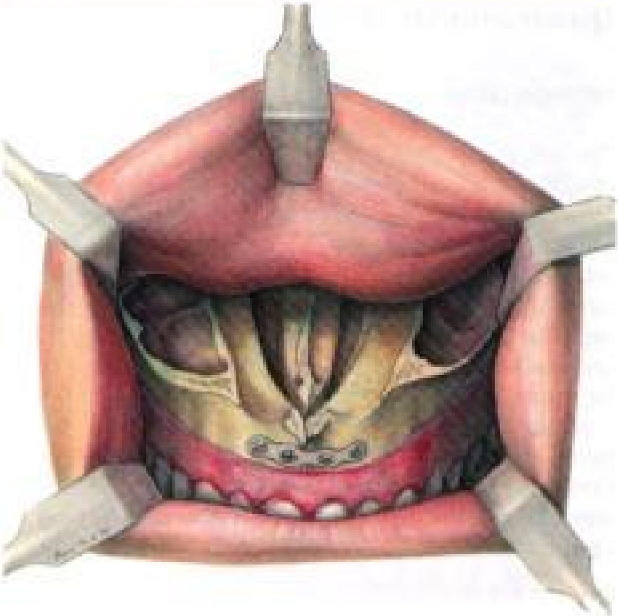

Fig. 18.**4** **Four-hole microplate bent around the nasal spine and fixed to maintain the transverse position of the expanded maxilla**

Fig. 18.**5** **Four four-hole plates to fix the extruded maxilla.** Interpositional bone graft in place

Quadrangular Osteotomy

Introduction

The quadrangular osteotomy, as introduced by Kufner (1960), is especially useful for patients with maxillary hypoplasia extending to the infraorbital and zygomatic area. Several modifications have been described, mostly related to the extent of the osteotomy in the lateral orbital wall and zygomatic area. The basic benefit from this osteotomy, however, is the improvement of infraorbital and malar projection when the whole zygomatic–maxillary complex is advanced, leaving the nose behind.

Miniplates and microplates will provide sufficient stability, if applied properly in strategic locations; additional intermaxillary fixation may be necessary for a few weeks because it is not always possible to achieve truly rigid fixation.

Technique

A modification developed by Stoelinga and Brouns (1996) is performed by an intraoral route. The nasal aperture, infraorbital rims and part of the lateral orbital wall with the zygomatic prominence is exposed via a vestibular incision, which is carried all the way to the back. The osteotomy runs to the infraorbital rim, although the bone cut runs around the infraorbital foramen, to prevent damage to the nerve. The lateral bone cut may be carried as far laterally as necessary, but should include the zygomatic bone. The extension in the lateral orbital wall depends on the needs of the patient. If that part needs to come forward as well, a coronal incision may be necessary to gain adequate access to this area (Fig. 18.**6**).

After advancement of the maxilla and temporary intermaxillary fixation, the mandibulary–maxillary complex is maneuvered into position. Bone grafts are contoured and used to bridge the gaps, particularly in the infraorbital region and the zygomatic and medial areas. An onlay graft is used to cover the infraorbital foramen, but care should be taken not to put pressure on the nerve. Fixation can be achieved by placing a four-hole plate in the zygomatic area, which crosses the gap on both sides (Fig. 18.**7**). If enough space is available, a second plate may be placed parallel to the first one.

There is not usually enough bone volume available to place another plate in, for instance, the medial area. The infraorbital 'wing' is typically very thin and the presence of the lachrymal duct precludes placement of screws in the lateral nasal wall. This often leaves the maxilla attached to only two or four plates in the posterior area, which theoretically may allow for a tilting movement. Intermaxillary fixation may therefore be necessary for a few weeks. The length of this period depends on the degree of mobility shown by the maxilla. This should be monitored closely by clinical examination or cephalometric evaluation.

Fig. 18.6 **Design of quadrangular osteotomy avoiding the course of the infraorbital nerve.** Dotted line represents extension in the lateral orbital rim, for which a coronal incision is necessary

Fig. 18.7 **One or two miniplates secured along the infra-zygomatic crest on both sides provide sufficient stability**

Le Fort II Osteotomy

Introduction

The Le Fort II osteotomy, introduced by Henderson and Jackson (1973), is designed to correct nasomaxillary hypoplasia or depressions resulting from trauma. Limited numbers of patients may benefit from this osteotomy but, when indicated, it serves its purpose well. It is particularly useful for patients suffering from Binder's syndrome and some cleft patients with a hypoplastic maxilla in conjunction with a depressed nasal bridge.

The best approach to the naso-orbital complex is achieved through a coronal incision. Plates used to fix the fragment, therefore, should be as small as possible, since their removal would require repeated coronal dissection. For this reason and because the bone to be used for osteosynthesis is usually thin and prone to break when larger screws are used, microplates are the best solution

Technique

Access to the nasomaxillary complex is gained through a coronal incision and dissection to the orbit and nasal bridge. An intraoral, vestibular incision will allow exposure of the infraorbital area and tuberosity. The infraorbital rim should be exposed through either a conjunctival or subciliary incision. After completing the bone cuts in the way described by Henderson and Jackson (1973), the nasomaxillary complex is mobilized and brought forward.When proper advancement has been achieved, intermaxillary fixation is applied and the mandibular–nasomaxillary complex is maneuvered into the desired position. Bone grafts are contoured and used to fill the gaps, especially in the nasal bridge area, the infraorbital rim and lateral sinus wall. In most cases it is necessary to use an onlay graft on the dorsum of the nose. For this reason careful subperiosteal–subperichondrial dissection should be performed, which may be carried as far distally as the tip of the nose.

An appropriate piece of cortical bone should be carved to fit the recipient site and inserted. Stabilization is achieved by fixing four-hole straight or L-shaped microplates along the nasal bridge and the infraorbital rims and, if possible, along the infrazygomatical crest (Fig. 18.8). The plates should be bent to adapt to the curvature of the bone and the steps and can be fixed with 4 mm or 6 mm micro screws.

At the end of the procedure intermaxillary fixation can usually be released, since four-point fixation will be adequate. Loose intermaxillary fixation with rubber bands may be used to guide occlusion if indicated.

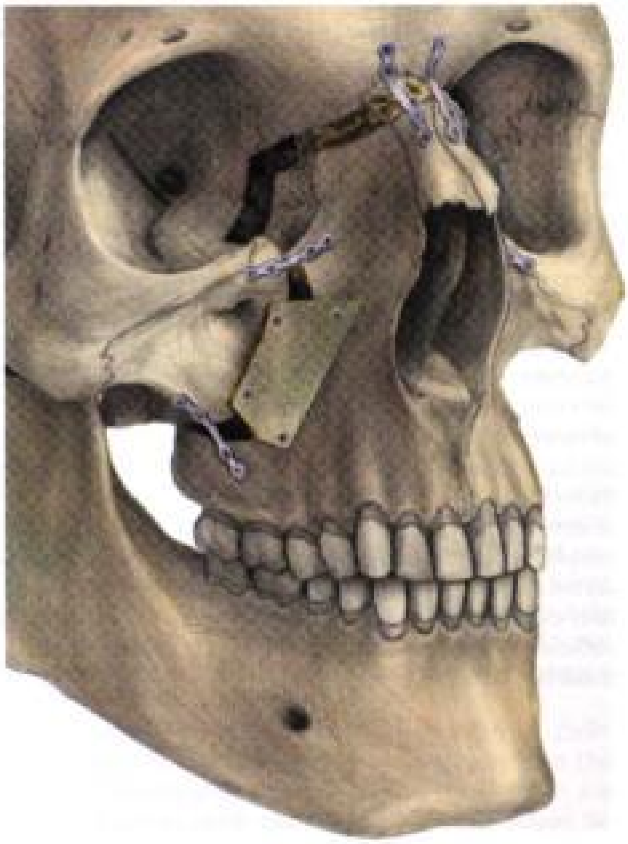

Fig. 18.8 **Maxilla advanced according to Le Fort II pattern.** Microplates along the nasal bridge, infra-orbital rim and infrazygomatical crest provide sufficient stability for advanced maxilla. Corticocancellous bone grafts are necessary to fill the gaps

Le Fort III Osteotomy

Introduction

The Le Fort III osteotomy (Gillies and Harrison, 1950; Tessier, 1967), carried out through a subcranial route, has only limited applications. Patients with nasomaxillozygomatical hypoplasia or recession because of trauma may be candidates for this type of osteotomy. Mild forms of telecanthus or hypertelorism may also be treated using a modified Le Fort III osteotomy. This osteotomy may also be carried out in conjunction with a Le Fort I osteotomy, if the hypoplasia in the dentoalveolar area is more pronounced than in the midfacial region. Miniplates and microplates may be used because usually relatively thick bone struts are available for screw fixation. Microplates, however, are preferred, because plate removal would almost necessarily imply exposure of the naso-orbital skeleton again, via a coronal approach. Miniplates tend to show through the relatively thin skin, whereas microplates can be left in place.

Technique

Just as in the Le Fort II osteotomy access to the maxillofacial skeleton is achieved by a combination of a coronal incision and dissection and an intraoral vestibular incision. Through this route the whole nasomaxillozygomatical area can be adequately exposed. The osteotomy is carried out as described by Gillies or Tessier or modified in any way to meet the needs of the patient. Once the osteotomy is complete, the whole complex is gently mobilized and brought forward. Intermaxillary fixation is applied and the mandibular–maxillary complex is maneuvered into place. Corticocancellous bone grafts are contoured to fit the defects that are the result of the advancement of the fragment. In particular, the lateral orbital rim and nasal bridge form ideal areas for plate fixation (Fig. 18.**9**). Miniplates or microplates are selected and bent to fit the anatomical situation. If possible, four-hole plates are selected in either shape to accommodate the needs. Since at least a four-point fixation can be achieved, the fixation can be considered sufficiently rigid to allow for immediate release of intermaxillary fixation.

Osteotomies in Cleft Lip and Palate Patients

Introduction

Maxillary osteotomies in cleft lip and palate patients are different in that scars limit the maneuverability of the fragments. The vascularization of the tooth-bearing area is also impaired both by scar tissue, because of previous operations, and anatomical aberrations inherent in the deformity. Several studies have shown that the stability of Le Fort I osteotomies using wire osteosynthesis is far from adequate. Segmental osteotomies as proposed by Tideman, Stoelinga, and Gallia (1980) appear to give rise to better results. This technique also allows for simultaneous closure of the alveolopalatal bony defect without putting the vitality of the fragments at risk.

At present, most patients with cleft lip and palate will undergo early secondary bone grafting at age 8–10 years. This allows eruption of the canine into the arch and orthodontic alignment of the teeth. Yet, in approximately 20% of such patients a Le Fort I osteotomy is indicated to correct a maxillary hypoplasia or misalignment of the dentoalveolar segments.

Abb. 18.**9** **Le Fort III osteotomy to advance the midface.** Note corticocancellous bone grafts in the gaps of the lateral orbital wall and nasal bridge. Microplates along nasal bridge and lateral orbital wall provide sufficient stability

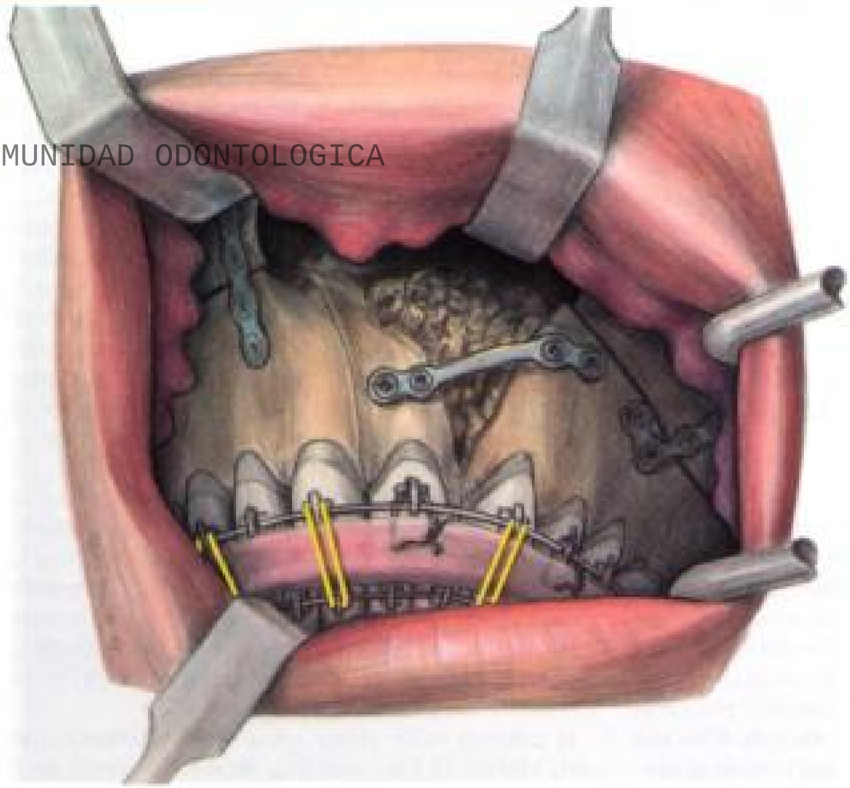

Fig. 18.11 **Maxillary segments in a patient with unilateral cleft palate have been secured with microplates.** One plate is used to bridge the clefts, which adds to the stability of the transverse repositioning. Bone grafts are used to fill the gaps and the alveolopalatal cleft

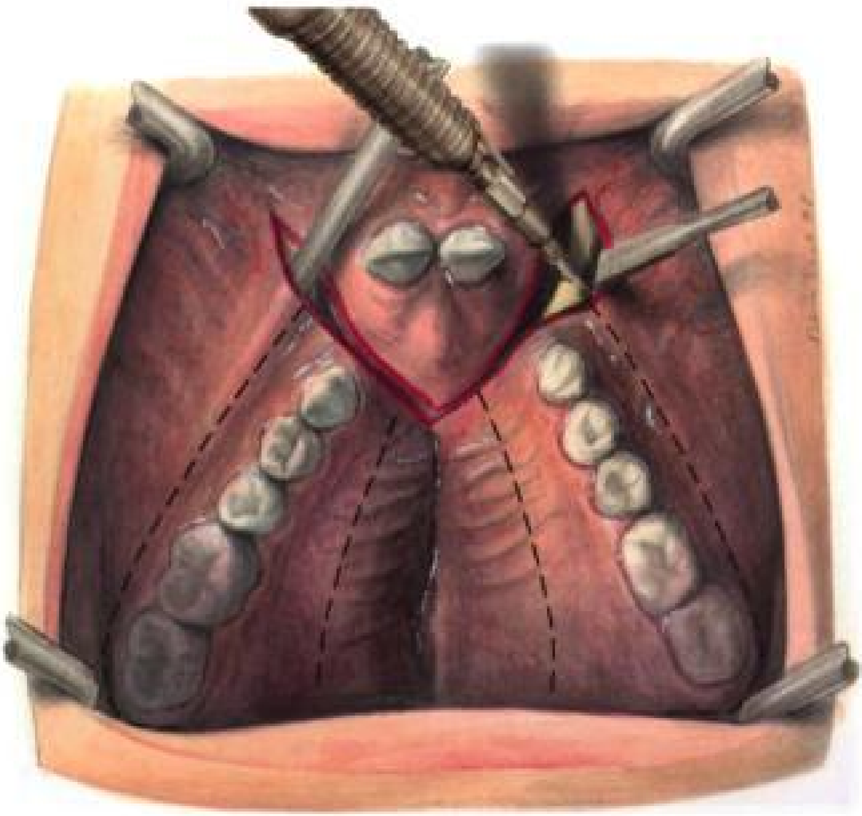

Fig. 18.12 **Incision used to approach the bilateral cleft lip and palate.** The two lateral fragments are approached through a tunneling technique

quately fixed. The acrylic splint in conjunction with the one plate will be enough to provide stability. In cases of bilateral clefts, in which there is not enough access to fix the posterior fragments with two plates each, fixation will probably not be rigid enough to allow for early release of intermaxillary fixation. In those patients a period of 4–6 weeks of intermaxillary fixation might be necessary to obtain a good result.

19 Orthognathic Surgery Distance Screws

Konrad Wangerin and Henning Gropp

Introduction

The simultaneous osteotomy of the maxilla and mandible, first described by Obwegeser in 1970, runs the risk of incorrect position of the maxilla, the mandible and both condyles, if it is done without full supporting actions, including (but not limited to) an exact diagnosis, preoperative orthodontics, operation planning (method and simulation) and careful postoperative control.The use of miniplates and microplates in the midface and the mandible has led to greater convenience for patients; nevertheless, without the additional supporting activities referred to above results will be dependent solely on the experience of the surgeon.Through the last quarter of the 20th Century, significant developments in such fields as operation planning, operation simulation and support skills and services have led to reproducible, lasting and stable results from this operation.

The double-splint method (Lindorf, 1977) is frequently used to control the horizontal dimension during the step-by-step positioning of maxilla and mandible in reaching a neutral occlusion. Controlling the vertical dimension is done intraoperatively by direct measurements between screw holes above and below the Le Fort I osteotomy line, or indirectly with extraoral appliances (Speculand and Jackson, 1984; Neubert, Bitter, and Somsiri, 1988; Luhr and Jäger, 1994), or intraorally using positioning plates (Wangerin, 1990).

Technique

After preoperative orthognathic treatment, extensive clinical diagnosis, planning and simulation of the operation are performed.

Clinical Diagnosis

First controlling, registration and consideration of the following clinical aesthetic parameters are necessary: Clinical esthetic parameters are considered and recorded, including the vertical facial symmetry embracing the harmony of the three parts of the medial section of the face, the laugh line of the upper lip and the profile of the face. The stomatognathic system is evaluated, including the chewing function, tongue and mimic muscle activities, condition of the teeth and the periodontium and function of both temporomandibular joints.

X-ray Diagnosis

A panoramic X-ray is taken to judge the position of the mandibular canal and the wisdom teeth, when present. A lateral cephalogram is made for the Bergen analysis (Hasund, 1974), which provides information about maxillary and mandibular growth. In cases of asymmetries of the face a posterior–anterior cephalogram is necessary to determine the skeletal dimensions of abnormal jaw growth. These analyses are the basis for planning the operation.

Model Diagnosis

The unstable malocclusion leads to an undefined position of the condyles (Fig. 19.1). Therefore a check bite in centric occlusion is performed to put the condyles in a physiologic position (Fig. 19.2). These condylar positions are monitored radiographically while using the check bite. Plaster models of the maxilla and mandible are made to analyze the orthodontically-aligned upper and lower dental arches.

Planning

Cephalometric measurements on the lateral cephalogram determine the planned maxillary displacement. The esthetic parameters are considered. Then the mandible is placed in neutral occlusion to the maxilla. After analysis of the new facial profile a decision is made to determine the chin correction.

Simulation

The model of the maxilla is cut at the level of the Le Fort I osteotomy line. The model of the mandible is cut at the lower border of the mandible. By using the centric check bite, which is equivalent to the first splint, these separate models are arbitrarily mounted in an individual articulator system, for example a SAM articulator, so that they are level with an upper plane corresponding to the lower border of the mandible. Thus both jaws can be shifted in their proper planes. Subsequently the maxillary model is loosened from the upper plane and fixed by means of glue in the new position. The second splint is prepared in this relationship.

Fig. 19.1 **Unstable class III malocclusion and anterior open bite with continuously changing occlusal contacts, intensified during orthodontic movement of the teeth, and permanently changing positions of both mandibular condyles**

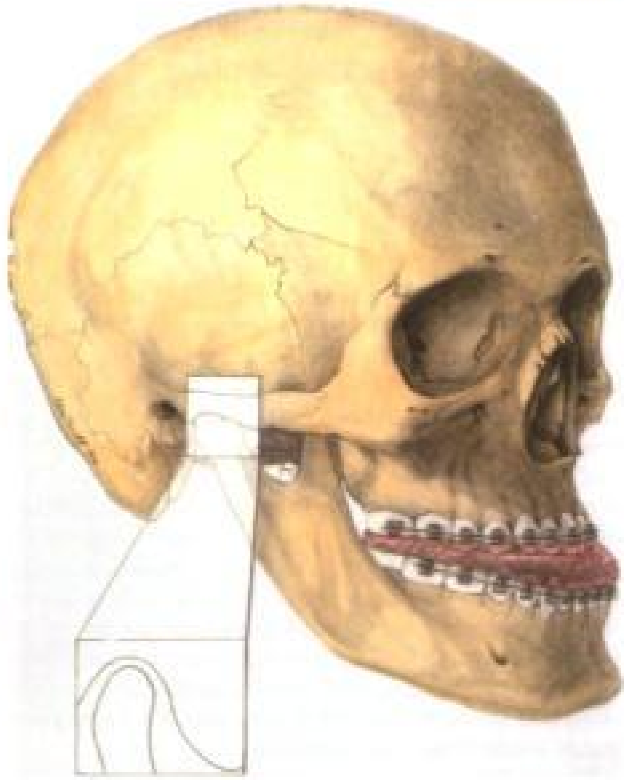

Fig. 19.2 **Preoperative normal positioning of both mandibular condyles by an occlusal splint, which determines the maxillomandibular relation**

The mandibular model is then loosened from the lower plane and brought into a neutral occlusal relationship to the maxilla. The mandibular model is glued to the lower plane, the difference in height being filled with plaster. The third occlusal splint is prepared.

If maxillary advancement is not possible, as for example in a case of extreme class III malocclusion with a deep bite of the upper frontal teeth, a fourth splint to spread the dental arches must be prepared first to perform this simulation.

Surgery

The maxilla is exposed from the piriform aperture to the maxillary tuberosities by a buccal marginal rim incision. In the mandible the buccal and lingual parts of the angles of the mandible are exposed by incising the gingiva from the premolars to the anterior edge of the ascending ramus, and by separating it from the inserting masseter muscles and the pterygoid muscles. The first splint is inserted, the condyles are placed in the physiological position and intermaxillary fixation is applied using rubber bands or wire ligatures.

Two rigid titanium positioning plates are bent to fit the distance from the body of the zygoma to the buccal surface of the mandible on either side, without tension (Fig. 19.**3**). They are fixed with two monocortical screws on each end and immediately removed. Their purpose is to enable the centric condyle–fossa relationships to be maintained during the operation.

Intermaxillary fixation is released and the first splint is removed. A Le Fort I osteotomy is performed and the maxilla is completely mobilized. The second splint is inserted and the mobile maxilla is fixed to the intact mandible by means of rubber bands (Fig. 19.**4**). The maxillomandibular complex can now be rotated cranially by a rotational movement in both temporomandibular joints (Fig. 19.**5**). The new position of the maxilla is controlled by the positioning plates which, refixed to the buccal surfaces of the mandible and after rotation of the maxillomandibular complex, rigidly fix the maxilla to the zygoma in its new position when the cranial screws are inserted on each side. Thus the position of the maxilla is controlled in all three dimensions and the maxilla is rigidly fixed with three-hole or four-hole or L-formed miniplates (Fig. 19.**5**). In cases of exact bone contact, the use of microplates is possible; in cases of distocranial maxillary movement lag screws are used. The preferred position for the screws is the zygomatic crest and the piriform aperture, the two anterior buttresses of the maxilla.

Fig. 19.3 **Surgery.** After placement of the first splint the mandible is fixed with both condyles in a normal position, using two rigid titanium positioning plates, which are bent to fit the distance from the body of the zygoma to the buccal surface of the mandible

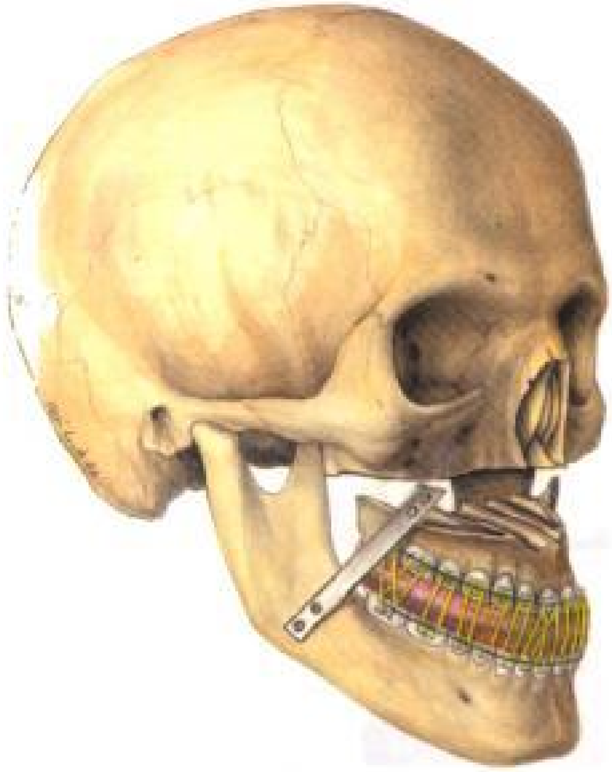

Fig. 19.4 **Surgery.** After Le Fort I osteotomy, total mobilization of the maxilla, placement of the second splint and fixation of the maxilla to the mandible, the maxillomandibular complex is autorotated, until the cranial plate holes correspond to the screw holes in the body of the zygoma. Control of the new position of the maxilla in three dimensions is possible

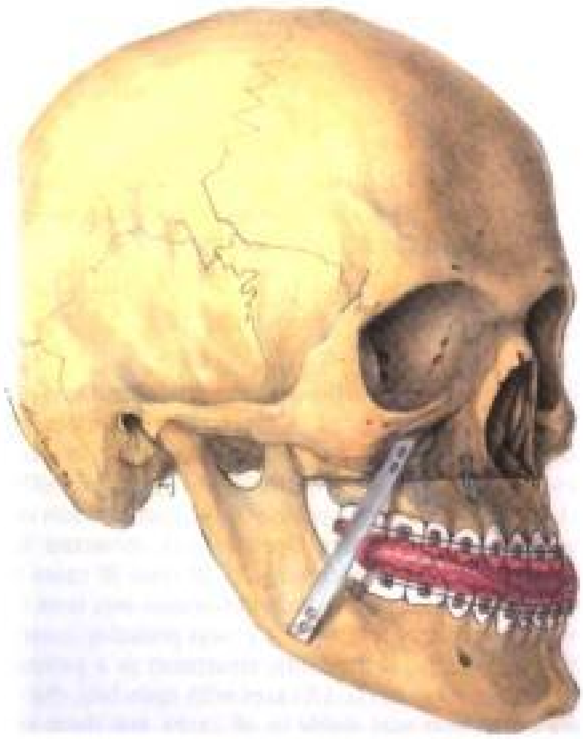

Fig. 19.5 **Surgery.** The maxilla is fixed in the planned new position by placement of plates at the zygomatic crests and piriform rims. The open bite is corrected and the maxilla is advanced in the planned position

Fig. 19.6 **Surgery.** Sagittal splitting of the ascending mandibular rami with removal of the buccal cortical plate and placing the mandible in the planned position, guided by the third splint

Fig. 19.7 **Surgery.** Loosening of the medial pterygoid muscle at the inner angle of the mandible to avoid the relapse movement of the mandible

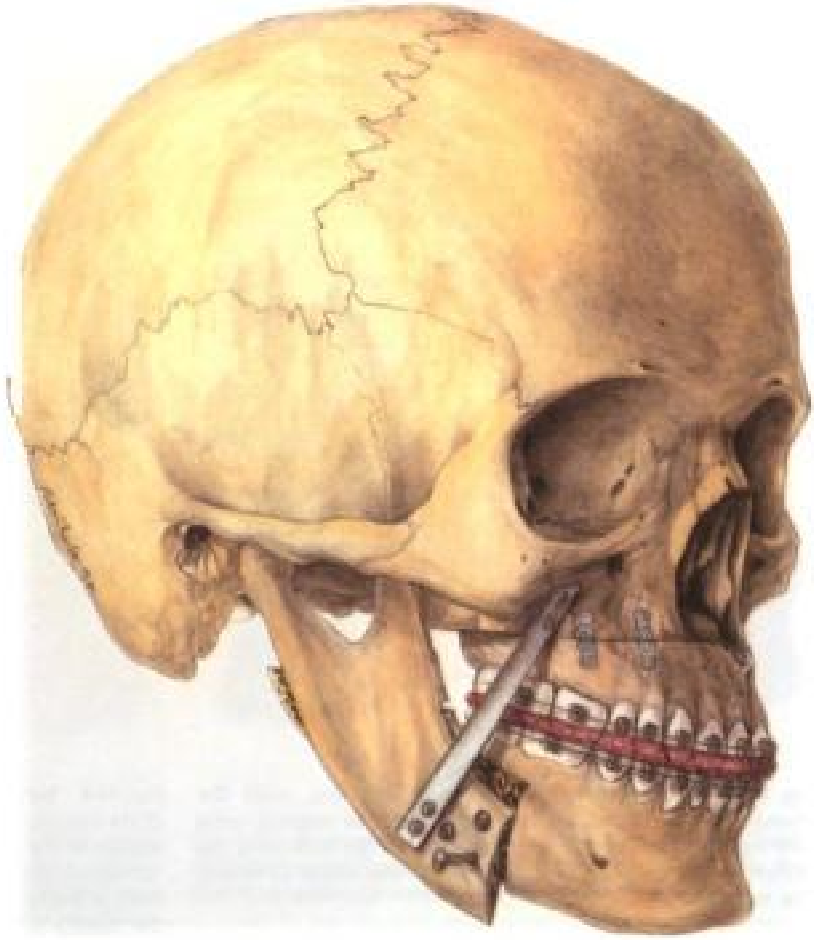

Fig. 19.8 **Surgery.** After using the third splint and after physiologic repositioning of both mandibular condyles, fixation of the mandible by means of transbuccally-placed position screws is performed

The positioning plates, intermaxillary immobilization and splint can now be removed again. Subsequently, the sagittal splitting of the mandibular rami is performed (Fig. 19.**6**, 19.**7**). After mobilization of the osteotomized mandibular body the third splint is inserted and wired to the maxilla. The mobile mandible is moved to fit the splint and fixed to the maxilla by rubber bands. The rigid positioning plates are inserted again to ensure correct positioning of the condyles by connecting the buccal surfaces of the mandible with the zygoma. By means of three or four position screws placed transbuccally into the mandible the condyles are kept in their physiologic position (Fig. 19.**8**). It is possible to use an angular screwdriver for the intraoral approach without an extraoral buccal stab incision. Miniplates on the buccal aspect of the mandible can be used to fix the sagittal osteotomies.

In cases where a patient has a cleft lip and palate the use of positioning plates is not recommended because of the risk posed by the disturbed blood supply to the maxilla. In these cases very limited bone exposure through the vestibular approach is not suitable for placing positioning plates.

Once intermaxillary fixation is removed, the new temporomandibular joint function is finally controlled by using the third splint for six weeks.

Skeletal Stability

One year postoperatively, perfect vertical and horizontal skeletal stability of class III cases after correction is reported (Hoffmeister and Wangerin, 1995). In class II cases, the maxilla is stable, but a horizontal mandibular relapse of 0.7° is seen because of the high tension of the surrounding soft tissue. Open bite is corrected in all cases by maxillary osteotomy. In all class III cases with open bite, a stable horizontal dimension was seen but a vertical maxillary relapse of 2.7° was probably caused by the preoperative orthodontic treatment or a pathologic tongue function. In class II cases with open bite, the open bite correction was stable in all cases, but there was a small horizontal and vertical maxillary relapse. The probable explanation is that the change of maxillary position in two directions, rotation and advancement,

seems to be a less stable movement. In these cases Wangerin and co-workers considered using a bone graft from the hip. If an open bite alone was corrected by maxillary osteotomy, there was an amazing skeletal stability after one year (Hoffmeister and Wangerin, 1995). Reoperation in 2% of patients was necessary because of bad splits, temporomandibular joint problems, or malocclusions.

Because of the good results achieved by this method, Hoffmeister and Wangerin (1995) have extended the indications for bimaxillary surgery to include correcting low false positions of the maxilla and mandible. Around 80% of class II and class III orthognathic surgery cases can be corrected by bimaxillary osteotomies.

When only mandibular surgery is indicated, the position screw technique can also be performed. Before sagittal split osteotomy is performed, mandibulomaxillary position plates are applied with the splint in a centric position and are taken out immediately.

After osteotomy, the mandible is brought into the class I position using a second splint and intermaxillary fixation is undertaken. The position plates are applied and position screws inserted. Once the position plates are removed, the planned mandibular position and occlusion are confirmed.

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Fig. 20.1 **Three-dimensional correction of the split-fix plate after fixation by two screws in the proximal segment.** The adjustable clamping element is in position. The clamping element holds the proximal and distal segments safely in place. After the mandible has been correctly positioned, the two distal screws are placed monocortically into the bone plate and the clamping element is then removed

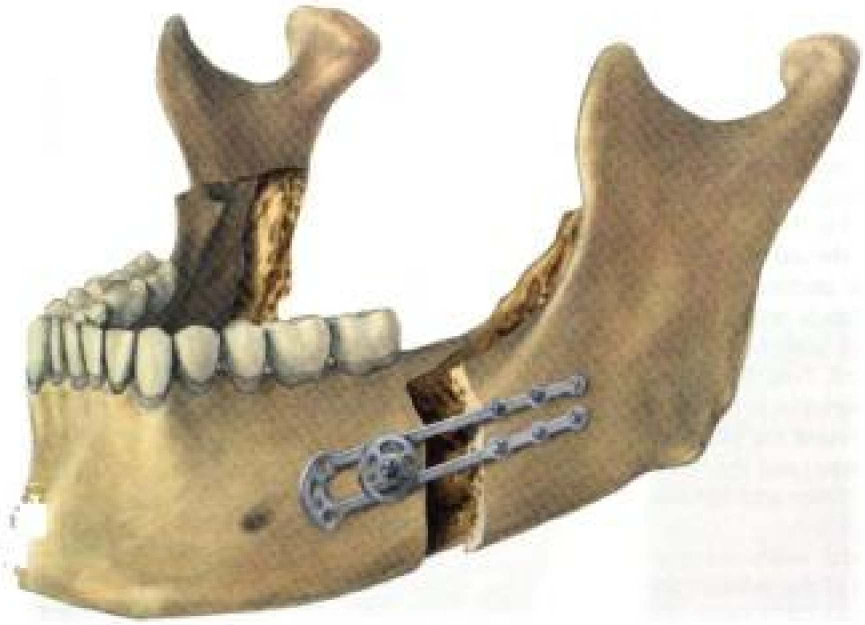

Fig. 20.2 **A modification of the adjustable miniplate.**

21 Craniofacial Surgery

Hermann F. Sailer

Hyperteloris m

The surgical correction of hypertelorism, perhaps the most breathtaking procedure seen in modern surgery, was developed by Paul Tessier (1967, 1972).

In principle, the operation consists of the cutting out of the orbits from the anterior and medial cranial fossae and medially rotating the upper midface with the orbital contents.

A coronal and a median transnasal and transfrontal approach is used to expose the anterior half of the skull, the supraorbital rims, the whole nasal skeleton, the lateral orbital rims and walls, the zygomatic complex and the infraorbital area as far as it is possible from the temporal access. Often a transconjunctival approach (Sailer, 1977; 1978) is used for better control of the median and lower orbital wall. The inner canthal ligaments are exposed and preserved and the periorbital tissues carefully stripped off the bone on all four sides of the orbit. The infraorbital area and the canine fossa is approached via an upper vestibular incision.

With the aid of preoperative planning using computerized tomographic scans, three-dimensional imaging, stereolithography models and the necessary clinical data (Sailer and Grätz, 1995), the craniotomy and osteotomy lines are outlined with a Toller burr (Fig. 21.**1**).

A simulation of the operation with the aid of a stereolithography model should always be performed. After the craniotomy, a supraorbital bandeau is removed and the anterior skull base, the crista galli, and the anterior olfactory nerve filaments are exposed. First the interorbital bone and most of the nasal skeleton is removed (Fig. 21.**2**), then gradually the bone around the olfactory nerve filaments (using magnifying loops) and the interorbital ethmoidal cells are removed (Sailer and Landolt, 1987 a, b).

The osteotomies through all orbital walls are performed behind the greatest diameter of the orbital contents; sometimes it is necessary to connect the osteotomies of the median orbital wall and the orbital floor via a transconjunctival approach (Sailer, 1978). The zygomatic complex is divided transversely, in an infraorbital direction (Fig. 21.**3**). The zygomatic osteotomy is completed below the infraorbital foramen into the piriform aperture beneath the lower turbinate, using an intraoral upper vestibular approach A triangular piece of bone above this osteotomy is removed from both sides of the piriform aperture. Both orbits are gently mobilized by finger pressure and by the use of broad chisels placed into the lateral orbital osteotomy.

Now two wires are placed within the glabella region and both orbits gently pulled and pressed together. The fixation of the supraorbital bandeau to the orbits and the calvaria is done mostly with titanium wires. A few miniplates can be used, preferably at the lateral orbital rim, in the zygomatic area for fixation of the lyophilized bone grafts (Sailer, 1992), and in the infraorbital region (Fig. 21.**4**). The defects in the cranial base and orbital walls are bridged by lyophilized cartilage slices (Sailer, 1992). The nasal frame work is reconstructed by an L-shaped strut of calvarial bone, which is fixed firmly to the glabella region by two mini screws (see Fig. 21.**4**).

At the end of surgery the surplus skin in the frontal and nasal area is excised along the median transnasal–transfrontal incision.

Correction of Craniosynostosis

The correction of the fronto-orbital area in a syndromal or non-syndromal craniosynostosis condition is based on the work of Tessier (1967) and Marchac *et al.* (1974). The most common fronto-orbital corrections have to be performed in scaphocephaly, frontal plagiocephaly, trigonocephaly and brachycephaly. The principles of correction of occipital scaphocephaly and occipital plagiocephaly (Sailer and Landolt, 1991) are described later.

Fronto-Orbital Corrections

The correction of a trigonocephaly condition is described as a typical example of fronto-orbital osteotomies . The aim of the procedure is to advance the supraorbital rims and the lateral forehead areas, in particular, to achieve a rounded natural skull form (Figs. 21.**5**, 21.**6**).

After the coronal incision the forehead, the supraorbital rims and the nasal structures (without detaching the inner canthal ligaments) are all exposed and the craniotomy and a supraorbital bandeau is outlined (see Fig. 21.**5**). For safety reasons, burr holes are placed laterally, away from the expected course of the superior sagittal sinus system (see Fig. 21.**6**). Usually six burr holes are made, though sometimes a maximum of eight is necessary. The most important part is the fronto-orbital bandeau; the osteotomies run over the fronto-nasal suture, along the anterior part of the orbital roof, through the zygomaticofrontal suture and from there far backwards within the frontal, sphenoidal, temporal and parietal bones, depending on the direction of the chosen osteotomy (see Fig. 21.**5**).

The fronto-orbital bandeau is totally removed and fashioned according to the desired plan. First the inner cortex of the glabella region is cut vertically to allow the supraorbital rims to be bent outward easily. Then, with a bone forceps, the lateral supraorbital area and the fingerlike extension of the bandeau are bent to the planned shape. The supraorbital bandeau is fixed to the nasal structure by a titanium microplate. The fingerlike posterior extension can be fixed to the parietal bone in the desired position using titanium wires, direct screws, microplates or resorbable osteosynthesis material (see Fig. 21.**6**).

The position of the fronto-orbital bandeau determines the width of the skull form and the angulation of the fronto-nasal region. The enlargement of the cranial width can now be seen by the space between the brain and the new position of the fronto-orbital bandeau.

A median strip of bone is fixed above the sagittal sinus system by wires or microplates (see Fig. 21.**6**). This bone strip defines the curvature of the forehead and the height of the skull. On both sides of the median bone strip the rest of the calvaria is now reconstructed as symmetrically as possible.

Fig. 21.**5** **Fronto-orbital correction in trigonocephaly (as modified by Sailer).** The osteotomies are arranged so that the sinus system is protected by a strip of bone in the median skull area

Fig. 21.**6** **The fronto-orbital bandeau is bent by a bone forceps so that the supraorbital rims are advanced and more prominent.** This bandeau is fixed by microplates. The median bone strip is fixed to the supraorbital bandeau and the parietal bone by titanium wires or microplates. The median bone strip determines the curvature of the forehead and also the height of the anterior skull. Defects in the calvaria are closed by lyophilized bone or cartilage

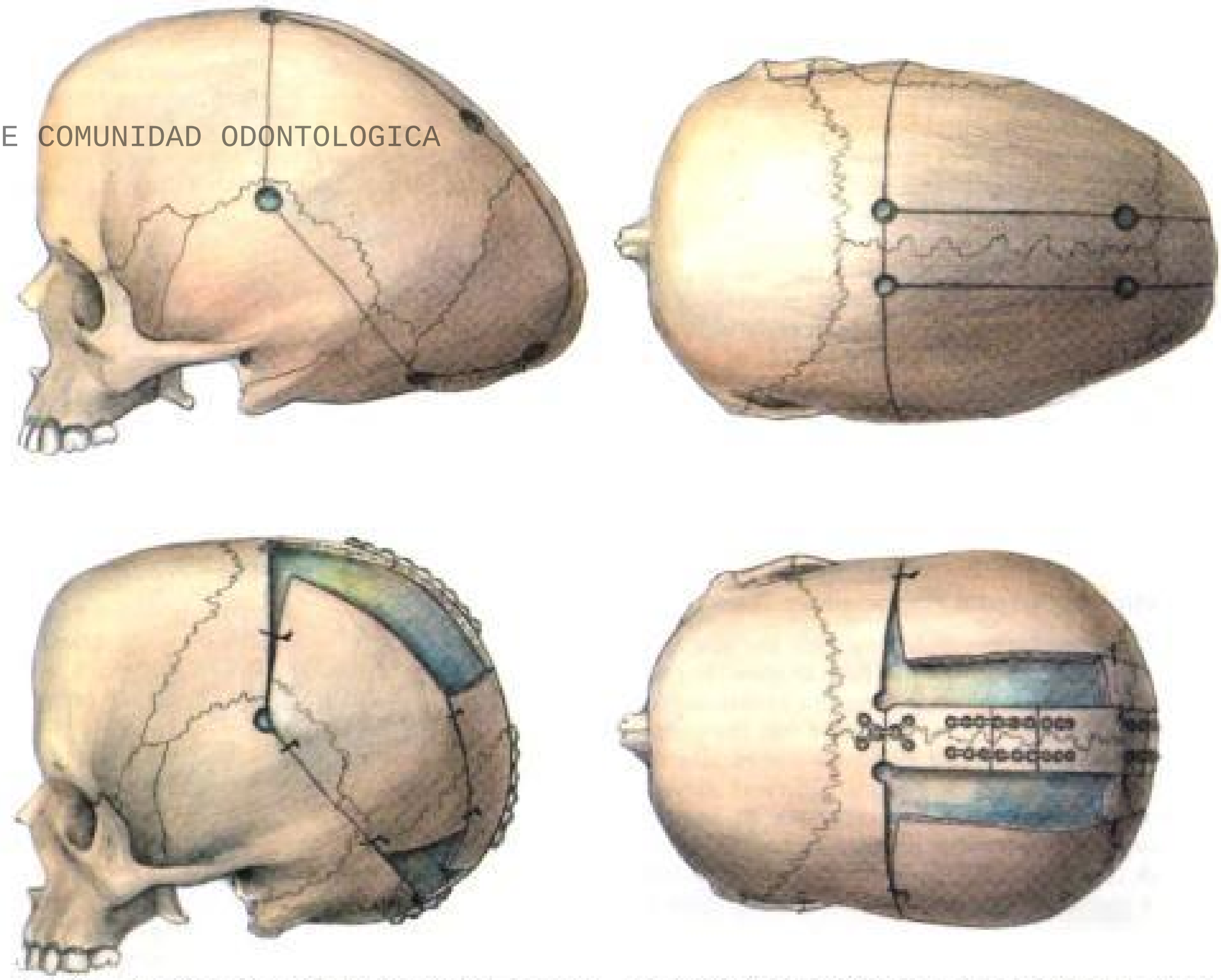

Fig. 21.7 **Correction of occipital craniosynostosis, according to Sailer, demonstrated in a scaphocephaly.** The head has to be shortened, widened and vertically extended. The key structure is a median bone strip running from the vertex to the deep occiput. The bone strip is given the desired form, height, and length of the skull, stabilized by miniplates and microplates and fixed to the parietal and occipital bone by plating. The residual bones are fixed on both sides of the median bone strip as symmetrically as possible. Residual defects are closed by lyophilized bone or cartilage. Immediately after surgery the patient can lie on the reconstructed occiput. The same procedure is used in occipital plagiocephaly

Fixation is done by titanium wires, microplates or resorbable plates. If the skull bones are very thin only wires can be used. Screws that are too long have to be cut to avoid trauma to the dura. Because the volume of the skull will be larger, there are always calvarial defects present. These defects are closed using either lyophilized bone (homologous calvarial bone or sternum) or most often lyophilized cartilage slices. It is well known that this kind of cartilage (Sailer, 1983) is transformed into the patient's own bone (Sailer, 1992).

Occipital Corrections

In severe cases of occipital scaphocephaly or plagiocephaly a correction is necessary for esthetic and functional reasons. In occipital scaphocephaly, the patient cannot lie on the occiput and the head is always falling sideways. In occipital plagiocephaly the patient always lies on the flat area of the head. The head cannot take a natural position during sleeping, which may also cause further functional problems of the vertebra, growth impairment etc. A special technique has been developed for surgical correction of occipital craniosynostosis (Sailer, 1991; Sailer *et al.*, 1998).

During surgery the patient is lying face downward to allow easy access to the posterior part of the skull. A coronal incision is made from ear to ear and the whole posterior part of the skull is exposed, down to the nuchal musculature. The osteotomies and the craniotomy are outlined so that a median bone bandeau is created that has the sagittal suture line in the center (Fig. 21.7). Usually 8–10 burr holes are necessary for the bilateral craniotomy.

Correction of Occipital Scaphocephaly

In a scaphocephalic condition the posterior skull form has to be made shorter, higher and wider (see Fig. 21.7).

This is accomplished by first shortening and bending the median bandeau, which is the key structure in the corrections of occipital craniosynostosis as the fronto-orbital bandeau and the anterior median bone strip is for anterior craniosynostosis operations. The median bandeau is segmented for this purpose and is stabilized by multiple titanium miniplates, microplates or both. The bandeau puts a moderate pressure onto the posterior cerebral structures. By doing this, the brain widens bilaterally and vertically. The median bandeau must be firmly fixed to the occipital and parietal bones by plates. It is the structure that has to carry most of the weight of the head immediately after surgery. The lateral parts of the skull are bent so as to achieve a symmetrical head form. There is no absolute need to use miniplates or microplates, exclusively, for stabilization of these lateral skull bones, if the median bandeau is well fixed as described above. A combination of wires and microplates can be used.

Correction in Occipital Plagiocephaly

In an occipital plagiocephalic condition the aim is to create a round symmetrical skull form to allow the child to lie comfortably on the occiput. Again a median sagittal bandeau is the key structure to achieve this. The plagiocephaly is always corrected bilaterally, diminishing the intracranial volume on the 'normal' side and allowing cerebral expansion on the affected side. In occipital plagiocephaly the median bandeau is usually turned through 180°, bent according to the desired form of the occiput and again stabilized and fixed in this form by miniplates. Then the missing bone structures are brought into position as symmetrically as possible on both sides. Osteosynthesis is done by microplates or miniplates, and wires, as described above (see Fig. 21.**7**).

Patients operated by using the median bone strip method clearly demonstrated better esthetic and functional results than patients operated without the median bone strip method (Sailer *et al.*, 1998).

High Midface Osteotomies

High midface osteotomies include frontofacial advancement, the pure Le Fort III osteotomy, the combined procedure of Le Fort III plus Le Fort I osteotomy, and the Le Fort III minus Le Fort I osteotomy. Combinations of these with correction of hypertelorism have been described (Sailer and Grätz, 1995).

Before miniplate osteosynthesis of the frontofacial area was used, there was a tendency to perform osteotomies of bigger units such as the frontofacial osteotomy in one block, the facial bi-partition procedure (Obwegeser *et al.*, 1978) and the pure Le Fort III osteotomy. These blocks could be stabilized by bone grafts and wiring. Thanks to rigid fixation it is now possible to stabilize smaller anatomical units using miniplates and microplates. This allows the position of every anatomical structure to be individually determined by segmental osteotomies, without the risk of relapse (Sailer, 1985; Sailer and Obwegeser, 1983). Use of miniplates and microplates in craniofacial surgery also allows reduction of the use of autologous bone grafts. If additional bone is necessary, homologous lyophilized bank bone in combination with miniplates and microplates can totally replace autologous bone in craniofacial surgery (Sailer, 1992).

Segmented Frontofacial Advancement Including Le Fort III plus Le Fort I Osteotomy in Two Parts

This procedure exemplifies several high midface osteotomies in one operation. The procedure should not be performed before adolescence (Sailer and Landolt, 1991).

The indication for this procedure is usually a syndromal craniosynostosis like the Apert's or Crouzon's syndrome with retrusion of the forehead, the infraorbital bony structures and the tooth-bearing part of the maxilla; the most striking symptom in these cases is the exophthalmos. Most of these patients show also a very high palate with narrow maxillary arches and an open bite.

The segmental frontofacial advancement procedure (Figs. 21.**8**–21.**10**) is performed using the 'sunglass' osteotomy (Sailer and Landolf, 1991); within the lateral orbital rims and lateral orbital walls a bony pillar is preserved on both sides from where the osteotomies of the orbital roof and the orbital floor are performed. The pillars serve as reference points for measuring the different movements and as fixation points for microplates and wires. The intraoperative timing demands that the osteotomy and mobilization of the midface by a Le Fort III osteotomy be performed first.

Before full mobilization of the midface is undertaken, a Le Fort I osteotomy can be performed and the tooth-bearing part of the maxilla mobilized using broad chisels. The palate can also be split parasagittally, to correct narrow arches.

Intermaxillary fixation is applied, followed by positioning of the zygomatic complex and infraorbital region on each side. Asymmetries of the infraorbital areas can be corrected by a paramedian splitting of the nasal bone, which allows for easier tilting of the zygomas according to need (see Figs. 21.**8**–21.**10**). The zygomatic bones are now fixed to the zygomatic arches, in combination with lyophilized bank bone, with miniplates, and to the lateral pillars, using microplates.

After this, the intraoral fixation of the maxillary halves takes place, again using miniplates and lyophilized bone. The nasal bones have not been fixed at this stage. The craniotomy is performed once the midfacial structures are stabilized.

This particular intraoperative sequence is necessary because it would be very difficult to mobilize the midface after craniotomy. The fronto-orbital bandeau is then osteotomized (as described earlier for isolated craniosynostosis) and advanced according to the preoperative

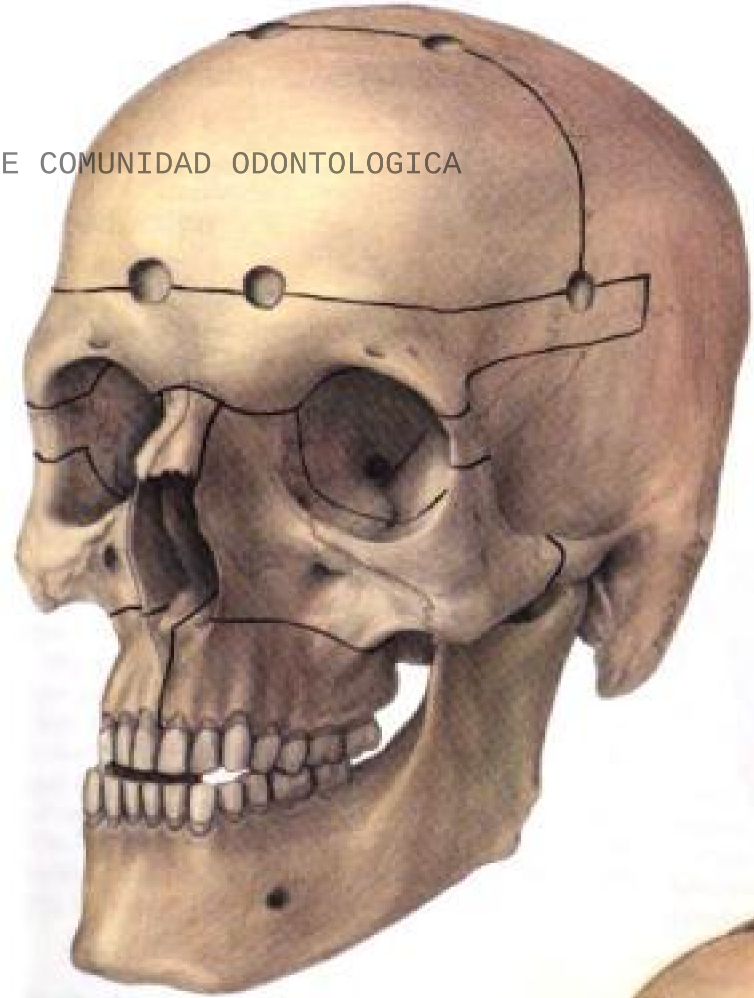

Fig. 21.8 **Osteotomy lines for segmented frontofacial advancement including Le Fort III plus I osteotomy.** This is indicated for severe forms of syndromal craniosynostosis and permits forward-positioning of the whole midface and fronto-orbital area

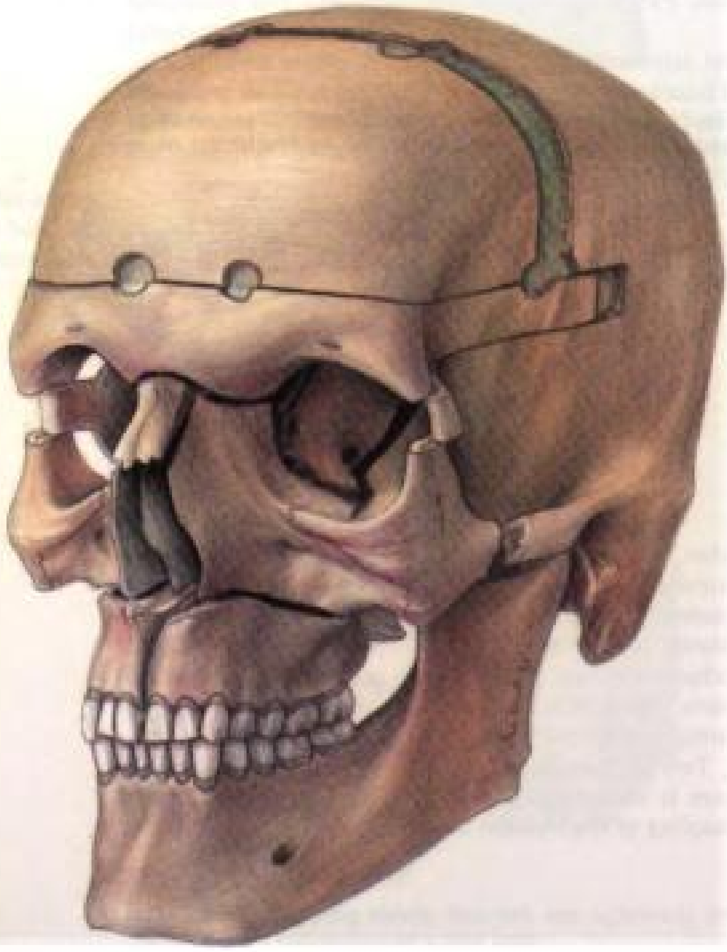

Fig. 21.9 **All anatomical key structures of the midface and the forehead are mobilized.** Note the paramedian nasal osteotomy which allows tilting of the infraorbital structures and of the zygomas, independent of each other

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22 Drill-free Screws

Klaus Louis Gerlach and Wolfgang Heidemann

Introduction

In craniomaxillofacial surgery, the use of self-tapping bone screws is now virtually universal in osteosynthesis to stabilize most skeletal and mandibular fractures and deformities. The requirement of drilling a pilot hole to use conventional self-tapping screws is a time- consuming extra step, which has some potential disadvantages. These include damage to nerves, tooth roots or germs, thermal bone necrosis, screw stripping due to an over-drilled pilot hole especially in thin cortical or soft cancellous bone, drill bit breakage, improper drill bit size selection and, finally, the extra cost of single-use drill bits.

Normally, self-tapping screws (Champy *et al.*, 1976b) have asymmetric threads with sharp edges to the screw shaft. The surface of the threads is nearly perpendicular to the direction of pull-out force, to provide maximum load transmission. The thread spirals around a cylindrical core with a pitch—the distance between the threads—of 0.75 mm or 1 mm. A cutting flute is engraved at the leading end of the threaded portion of the screw (Fig. 22.**1**).

Technique

After a pilot hole, of a diameter comparable to that of the screw's core, is drilled, the sharp flute cuts the bone in preparation for the threads further along the screw shaft as the screw is turned (Fig. 22.**2**).

The ability to insert drill-free screws without the need to drill pilot holes beforehand was enabled by changing the tip of the screw. The pointed screw tip with its thread is comparable in design and function to a corkscrew. Here, in contrast to self-tapping bone screws, the threads are spiraled along a cone-shaped axis of rotation up to the screw's peak. Again, the thread pitch is 0.75 mm or 1 mm An additional cutting flute cuts part of the bone like a chisel and acts as a channel for the removal of bone chips produced at the cutting site. The threads cut into the bone must not be broken or compressed. After drill-free screws are inserted, bone dust accumulates around the screw head (Figs. 22.**3**, 22.**4**).

Drill-free screws are available in both micro (1.5 mm) and mini (2 mm) diameters. In a comprehensive experimental trial Heidemann *et al.* (1996) compared different parameters (such as insertional, maximum torque and, especially, the pull-out force) of common titanium self-tapping micro screws and mini screws with drill-free screws of the same size. Test materials included mandibular cortical bone of pigs and, to enable a statistical comparison between the parameters of the screws used, hardwood and PVC as a homogenous substance with constant material qualities.

Depending on the thickness of the test material, the measured pull-out force of drill-free screws was found to lie between 70% and 104% of that of self-tapping screws. The maximum torque in bone and wood was comparable

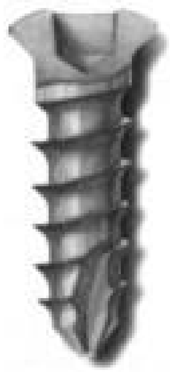

Fig. 22.1 **Technical design of a self-tapping screw**

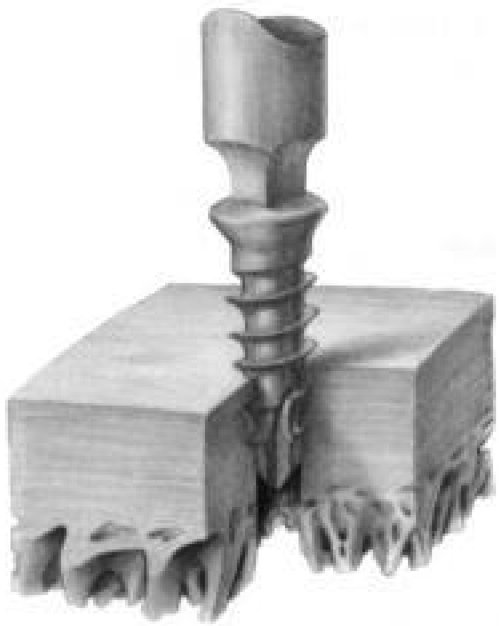

Fig. 22.2 **Self-tapping screw.** Insertion and tightening into the bone after preparation of a pilot hole

23 Reconstructive Preprosthetic Surgery and Implantology

John I. Cawood

Introduction

Reconstructive preprosthetic surgery can be defined as the restoration of oral function and facial form, rendered deficient through loss or absence of teeth and related structures, by a combination of surgical and prosthetic means. Nowadays the application of endosteal implants has extended the scope and effectiveness of reconstructive preprosthetic surgery (Cawood and Stoelinga, 1996). Of the many variables that govern the use of such implants the availability of sufficient bulk of bone is the most important. There is a progressive reduction in the residual alveolar ridges, following the loss of teeth, due to alveolar bone resorption, which occurs relatively rapidly in the first year after tooth loss and then continues at a slower rate for many years (Tallgren, 1972). This process occurs to a greater extent in the mandible compared to the maxilla and leads to a quantitative and qualitative reduction of the alveolar bone.

Cawood and Howell (1988) analyzed patterns of alveolar resorption and described a pathophysiological classification of alveolar resorption which is accepted internationally (Figs. 23.1, 23.2).

When considering reconstructive preprosthetic surgery of the edentulous jaw it is important that the clinician fully understands the anatomical consequences of reduction of the residual ridges. Based on a classification of the edentulous jaws, changes in the relationship of the jaws to each other, in muscle relations and function, in the oral mucosa and in facial morphology have been measured relative to the stage of resorption of the edentulous jaws (Cawood and Howell, 1991).

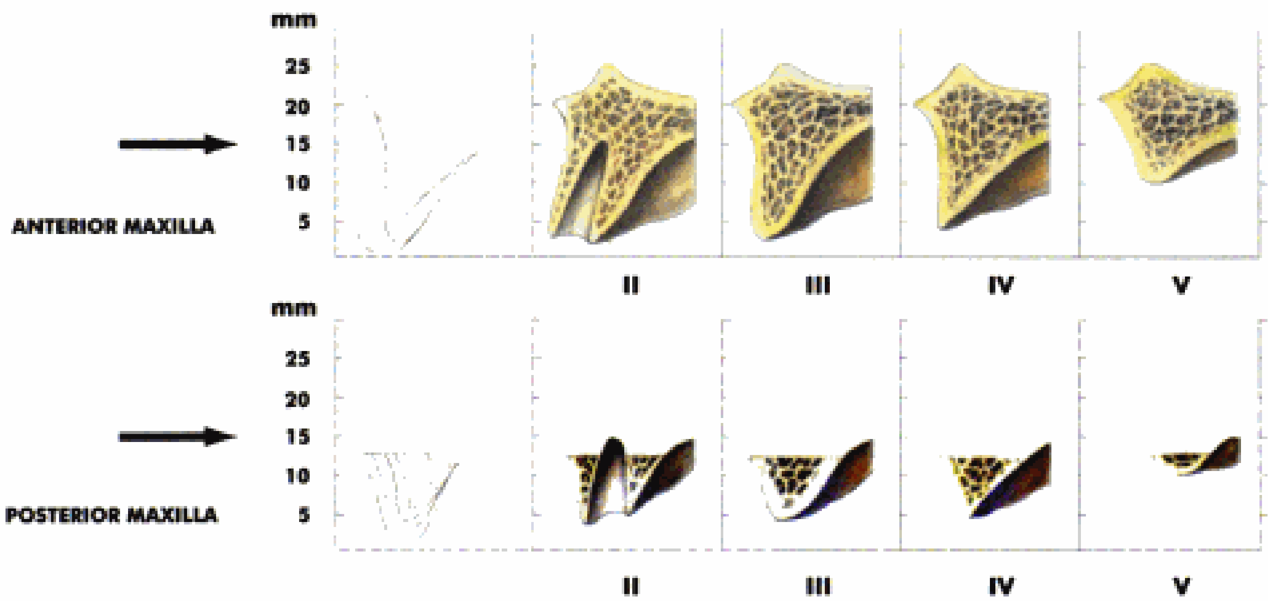

Fig. 23.1 **Classification of edentulous jaws (maxilla).** Class II, post dental extraction; Class III, broad alveolar process; Class IV, narrow alveolar process; Class V, flat ridge (loss of alveolar process)

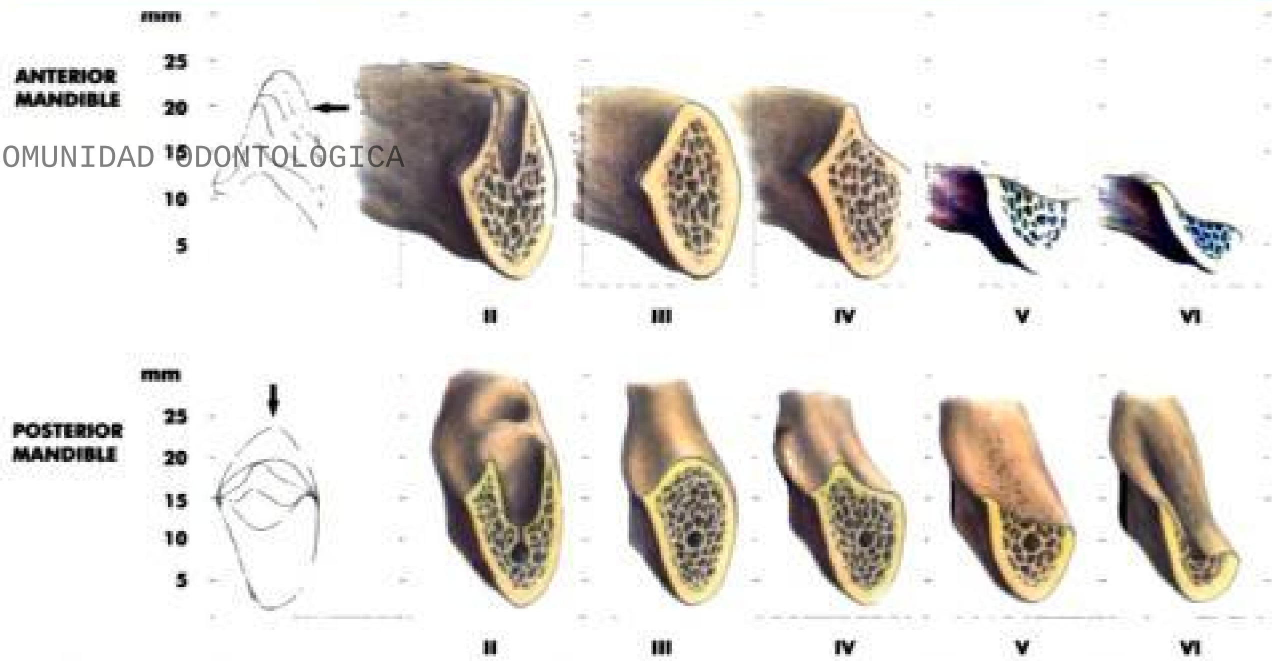

Fig. 23.2 **Classification of edentulous jaws (mandible).** Class II, post dental extraction; Class III, broad alveolar ridge; Class IV, knife edge alveolar ridge; Class V, flat ridge (resorption of alveolar process); Class VI, submerged ridge (resorption of basal process)

Anatomical Consequences of Jaw Atrophy

Interarch Changes

With progressive resorption from class I to class VI there are three-dimensional changes in jaw relations. Anteroposteriorly the mandibular and maxillary arches become shorter. Transversely, due to the pattern of resorption, the maxillary arch becomes progressively narrower while the mandibular arch becomes progressively broader. Vertically the interarch distance increases, although this is counteracted to some extent by the vertical shortening of the lower face caused by the autorotation of the mandible producing a more prominent chin and prognathic jaw relationship (Figs. 23.3–23.5).

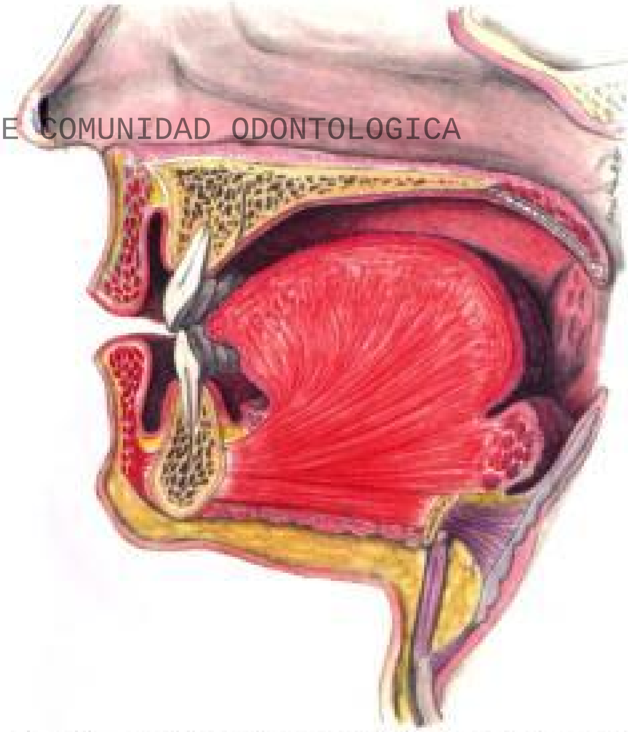

Fig. 23.3 **Dentate jaw.** Normal dental, jaw and soft tissue relationships

Fig. 23.4 **Edentulous jaw.** Encroachment of lips, tongue and floor of mouth associated with jaw atrophy

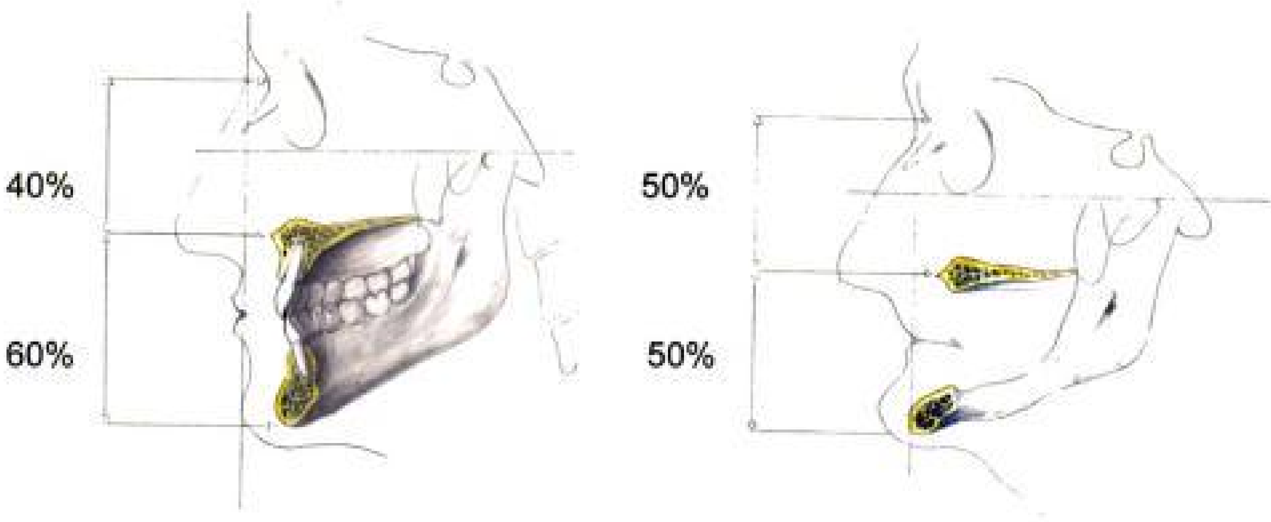

Fig. 23.5 **Consequences of jaw atrophy.** Decreased lower face height, relative prognathism, and collapse of lower facial soft tissue are shown

Muscle Changes

The attachments of the circumoral musculature and that of the floor of the mouth delineate the extent of the vestibular and lingual sulci. With the continued loss of alveolar bone from class I to class VI these muscles become progressively more superficial (Fig. 23.**6**).

Mucosal Changes

In the edentulous jaw, the mucosa covering the residual ridge is partly keratinized attached mucosa and partly unattached mucosa. With the resorption of the alveolus, the quantity of both attached and unattached mucosa diminishes significantly. In the mandible, as a result of alveolar bone loss, the inferior alveolar canal becomes relatively superficial (Fig. 23.**7**). In the dentate mandible the blood supply is principally centrifugal, arising from the inferior alveolar artery and periodontal arcades. However, in the edentulous mandible the blood supply is principally centripetal, arising via the subperiosteal plexus of vessels (Fig. 23.**8**).

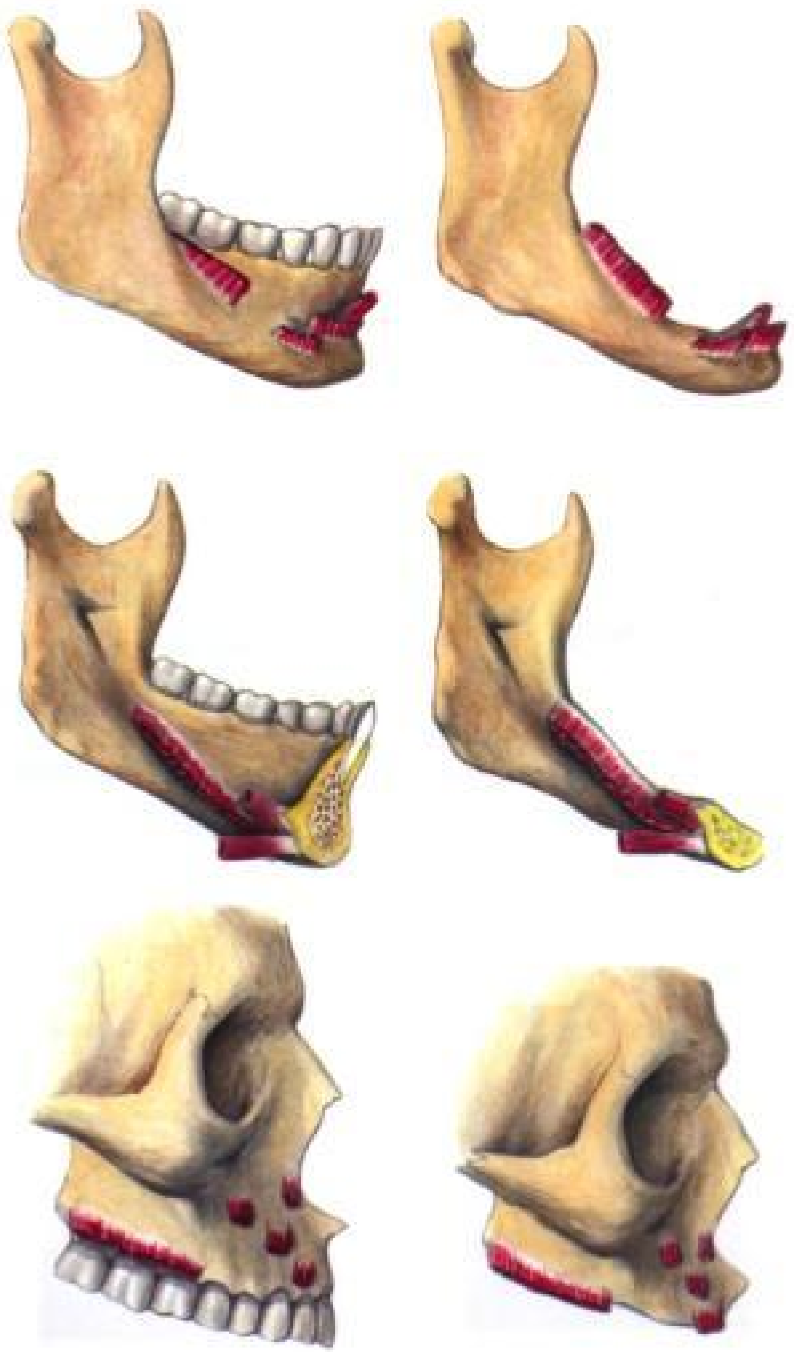

Fig. 23.**6** **Consequences of jaw atrophy.** The attachment of the circumoral and floor-of- mouth musculature delineates the extent of the vestibular and lingual sulci. With continued loss of alveolar bone from class I to class VI these muscles become progressively more superficial

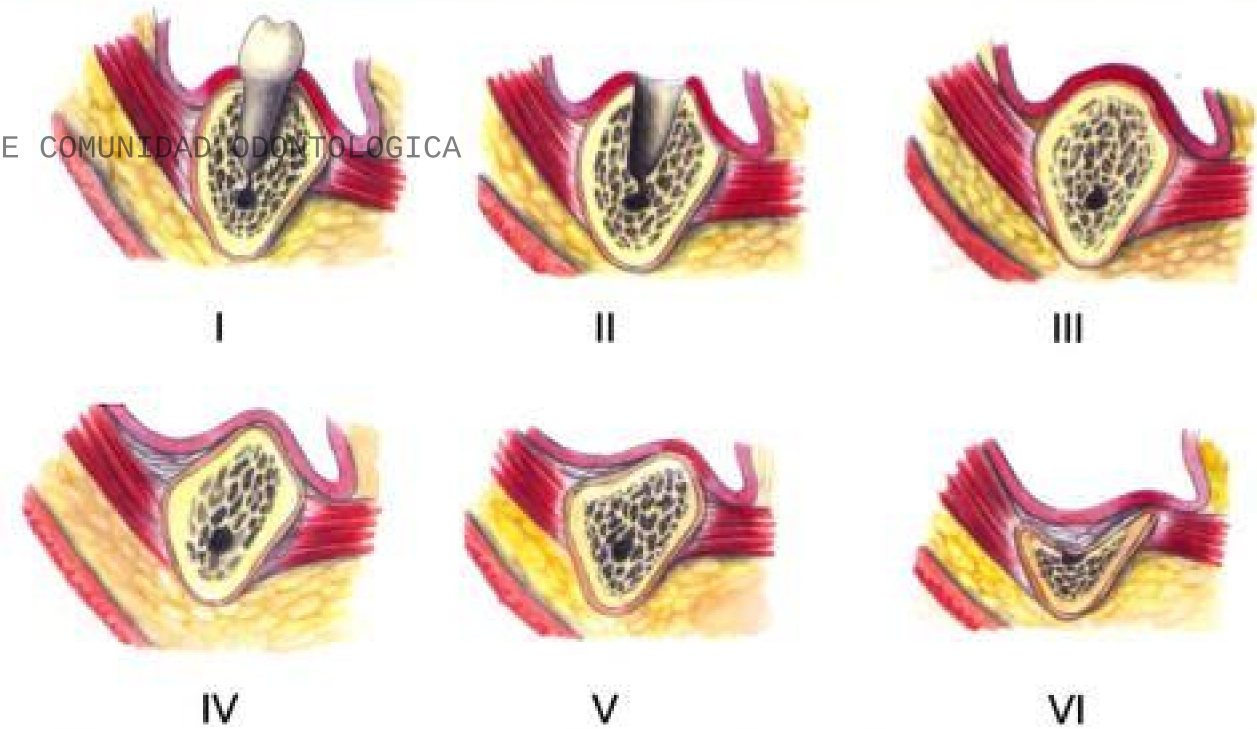

Fig. 23.7 **Consequences of jaw atrophy (posterior mandible).** Progressive reduction of residual ridge from class I to class VI results in decreased attached mucosa and in muscle encroachment. The inferior alveolar canal becomes more superficial

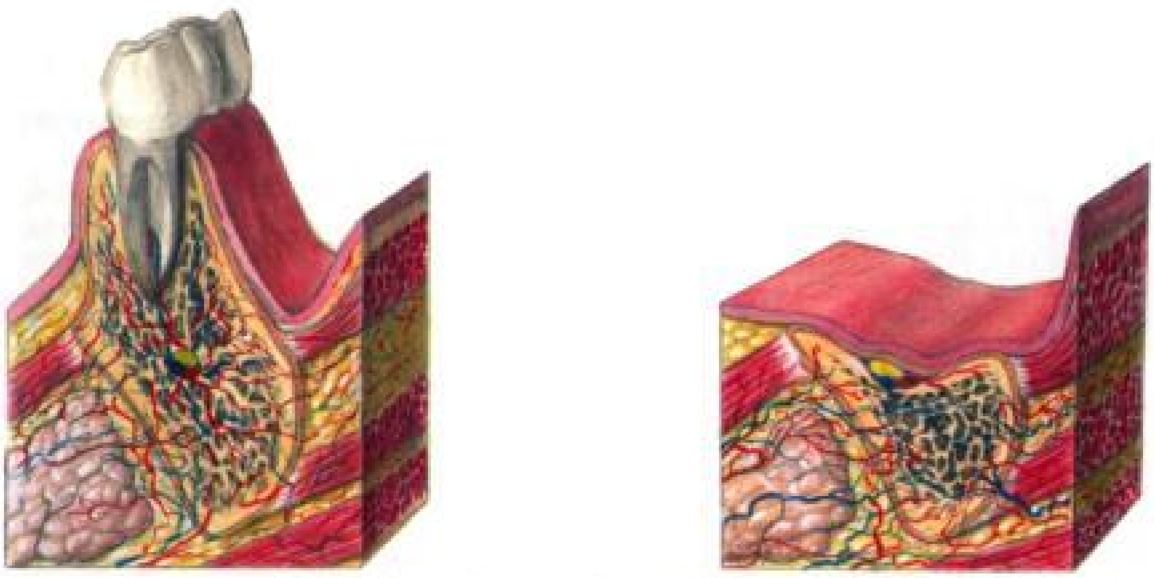

Fig. 23.8 **Consequences of tooth loss and jaw atrophy (mandible).** This results in alveolar resorption, loss of sulcus, and decreased and altered blood supply (centrifugal in the dentate jaw, centripetal in the edentulous jaw)

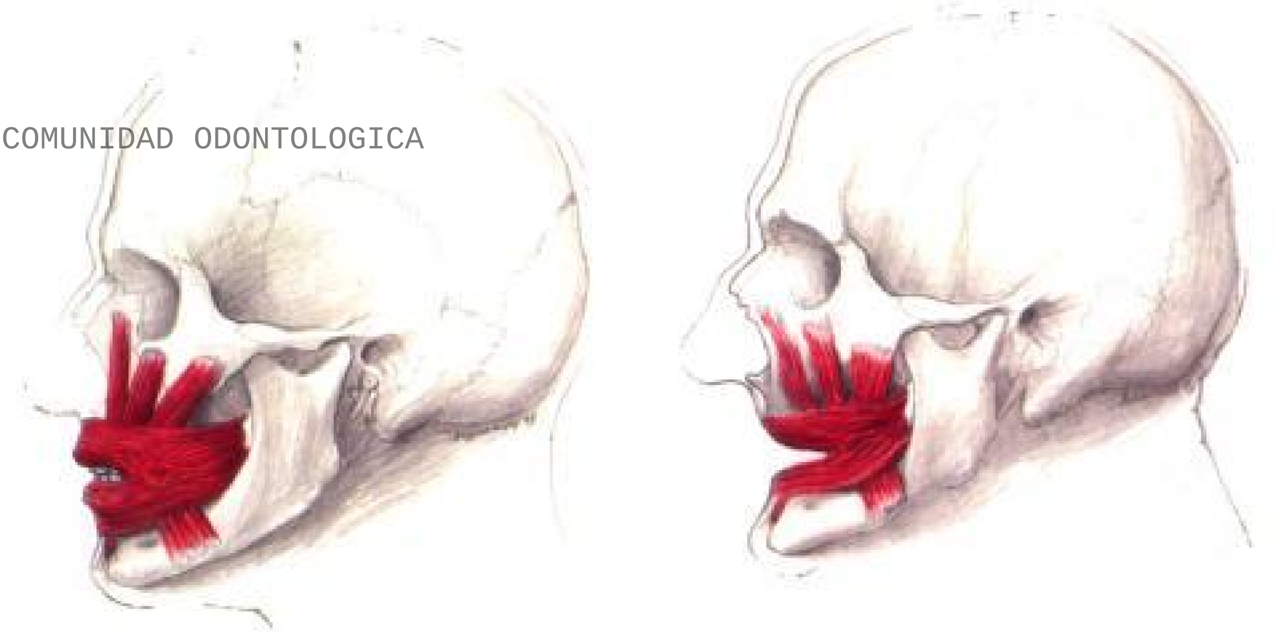

Fig. 23.9 **'Dental bulge.'** Tooth loss results in loss of the 'dental bulge' causing distortion of the circumoral musculature

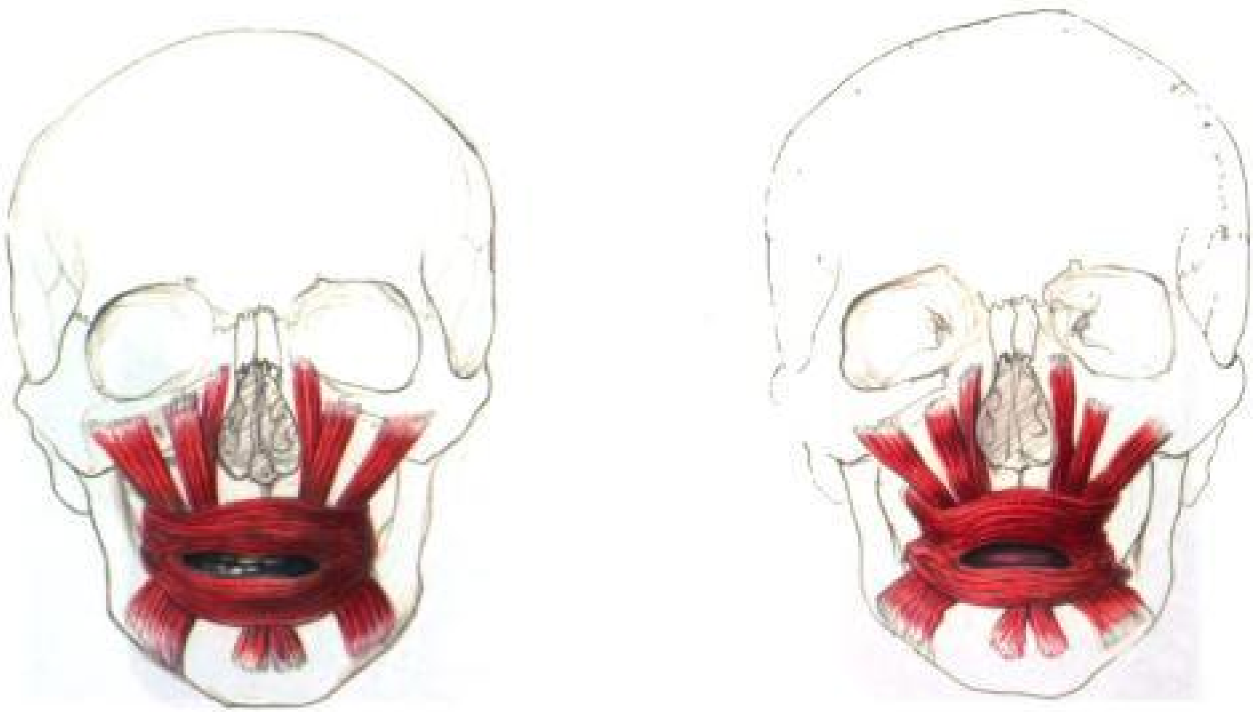

Fig. 23.10 **Consequences of jaw atrophy on circumoral musculature.** This results in circumoral hypotonia, contraction of orbicularis oris muscle, and distortion of muscles of facial expression (elevators and depressors)

Facial Changes

Watt and MacGregor (1976) liken the circumoral and facial musculature to a curtain draped between the maxilla and mandible. Loss of the anterior dentition results in loss of the 'dental bulge' and causes a shortening of the buccinator muscle and consequent distortion of the facial curtain (see Fig. 23.9). The muscles of facial expression decussate to form the modiolus and also intersect directly with the fibers of the orbicularis oris muscle. With tooth loss and reduction of the residual ridge there is hypotonia of the orbicularis oris muscle and the muscles of facial expression. The position of the modiolus changes, being pulled inward and backward, resulting in contraction of the orbicularis oris muscle and distortion of the muscles of facial expression (Figs. 23.9–

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Fig. 23.17 **Axial view showing maxillary osteoplasty with interpositional bone graft and stabilization of osteoplastic flaps with microplate osteosynthesis**

Fig. 23.18 **Subsequent placement of endosteal implants into augmented maxillary ridge** (implants are placed as a secondary procedure)

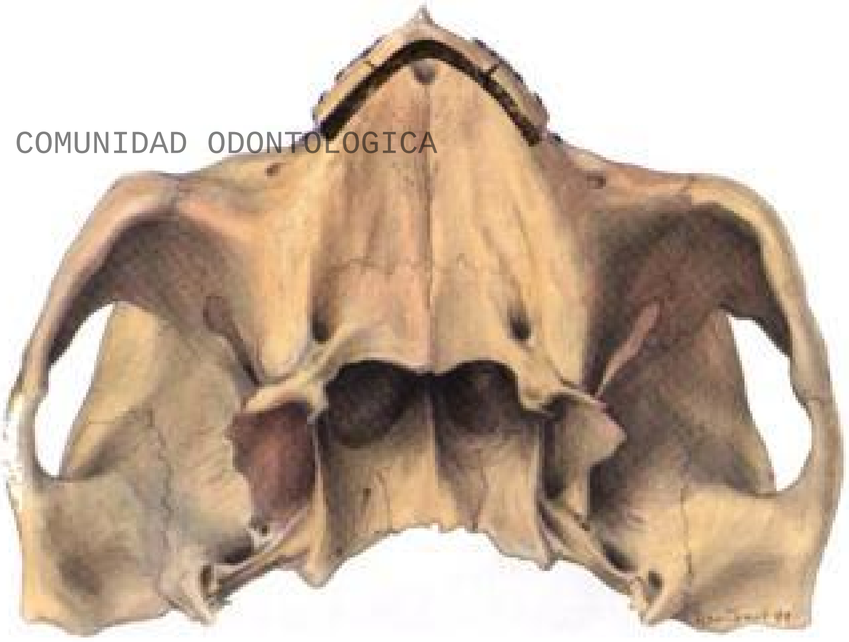

Fig. 23.19 **Anterior maxillary osteoplasty.** Multiple segments are stabilized with microplate osteosynthesis to expand the narrow V-shaped ridge at same time as broadening the narrow ridge

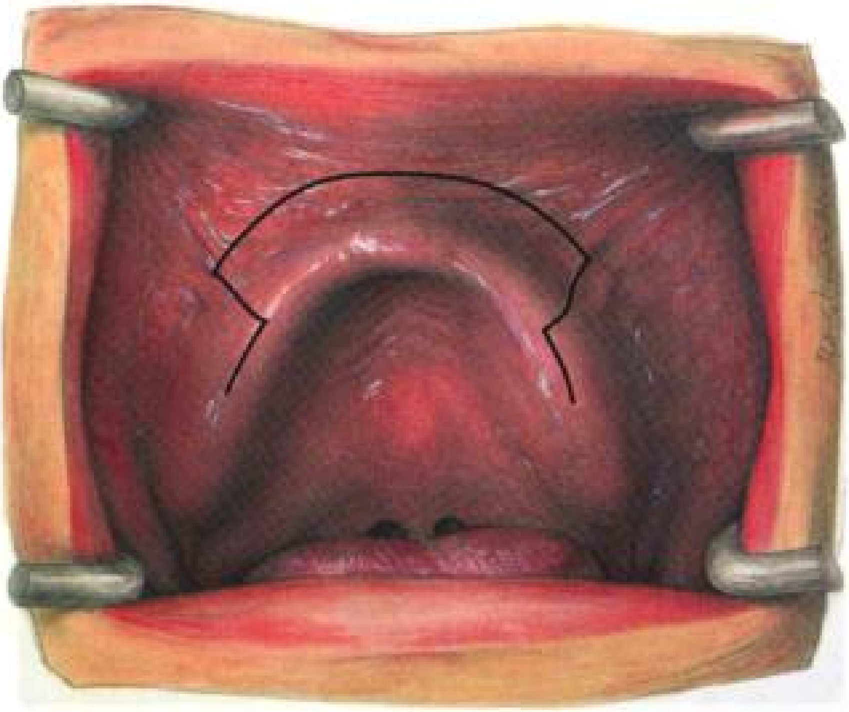

Fig. 23.20 **Combined anterior maxillary osteoplasty and 'sinus lift' procedure.** Position of mucosal incisions

the transverse width of the maxilla as well. This is achieved by dividing the anterior segment into two or three separate pieces. The osteotomized segments can be rigidly stabilized with microplates and screws (Fig. 23.**19**). This procedure can also be combined with the 'sinus lift' to allow placement of endosteal implants both anteriorly and posteriorly (Figs. 23.**20**–23.**22**).

Where there is fusion of the cortical plates, that is to say no intervening cancellous bone, the osteoplasty and interpositional bone graft technique is contraindicated. In these cases augmentation of the maxilla can be accomplished using block cortical cancellous grafts stabilized with position screws or with lag screws.

Fig. 23.21 **Combined anterior maxillary osteoplasty and 'sinus lift' procedure.** Position of osteotomy cuts

Fig. 23.22 **Combined anterior maxillary osteoplasty and 'sinus lift' procedure.** Frontal view of augmented areas

Class V Maxilla

Resorption of the maxillary alveolar process eventually leads to a relatively posterior and cranial position of the maxilla, resulting in a reversed intermaxillary relationship and increased vertical intermaxillary distance. Reconstruction of the class V maxilla aims at restoration of interarch relationship and augmentation of the alveolar bone to provide support for the collapsed facial musculature.

A revolutionary method to treat the class V maxilla was described by Sailer (1989). He proposed a Le Fort I osteotomy in which the maxilla is repositioned forward and downward at the same time. Cortical cancellous block bone grafts are placed in the floor of the maxillary sinuses and in the floor of the nose. The caudal segment and bone grafts are stabilized with miniplate osteosynthesis and endosteal implants inserted simultaneously. Cawood and Stoelinga (1994)described a two-stage procedure to augment the atrophic maxilla, involving a Le Fort I osteotomy and interpositional bone graft using particulate cortical cancellous bone (to take advantage of the more rapid vascularization and increased osteogenic potential of particulate cancellous bone over block cortical cancellous bone grafts) (Fig. 23.**23**). Following healing of the bone graft endosteal implants are inserted in an optimal position using a surgical guide.

Atrophic Mandible

Unlike the maxilla, which is composed of trabecular bone predominantly with a thin cortex, the mandible has a thicker cortical layer, similar to a long bone. This provides superior support for endosteal implants particularly in the anterior mandible. Following tooth loss and ageing, the blood supply of the edentulous mandible differs from that of the dentate mandible. In the dentate mandible of the younger patient, blood supply is mainly centrifugal, that is to say arises from the inferior alveolar artery and periodontal arterial arcades (see Fig. 23.**8**). The blood supply to the edentulous mandible in the older patient is mainly centripetal, being derived via the subperiosteal plexus (see Fig. 23.**8**). Therefore, when carrying out preprosthetic surgery of the edentulous mandible, raising of the mucoperiosteum must be performed carefully to avoid damaging the periosteal layer and ischemic necrosis of the underlying bone.

Class II and Class III Mandible

Endosteal implants can be inserted into the class II and III mandible with minimal pre-implant surgery being required. However it should be noted that any surgical interference with the inferior alveolar nerve may lead to sensory alteration and loss.

Fig. 23.**23** **Augmentation of Class V maxilla with interpositional bone graft following Le Fort I osteotomy with inferior and anterior repositioning of the caudal fragment**

Class IV Mandible

In the Class IV anterior mandible, contouring to remove a narrow ridge or onlay bone grafting may be required, to obtain sufficient bone bulk to accommodate endosteal implants.

Class V Mandible

In the anterior mandible, bone grafting is not usually required as there is sufficient residual bulk of bone to provide implant anchorage. However, where the soft tissue environment is unfavorable, either an interpositional bone graft or onlay bone graft may be required to prevent unfavorable soft-tissue encroachment, which would interfere with prosthetic function.

Class VI Mandible

To obtain sufficient volume of bone to place endosteal implants and provide optimal biomechanical function and soft-tissue support then either an interpositional bone graft or onlay bone graft is usually indicated (Fig. 23.24).

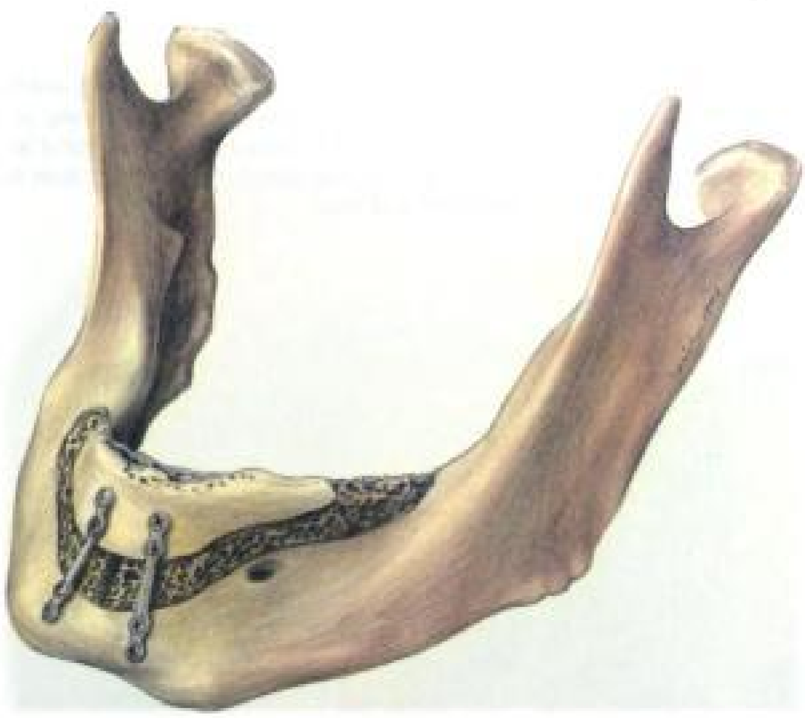

Fig. 23.24 **Mandibular augmentation with interpositional graft and stabilization with osteosynthesis plate**

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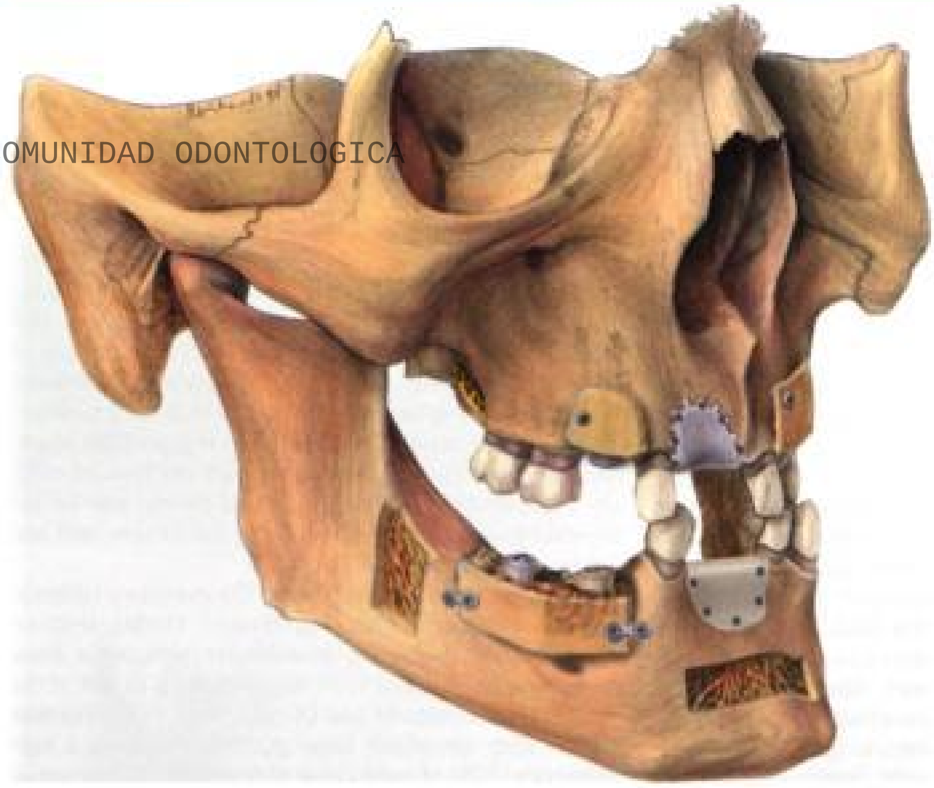

Fig. 24.2 **Fixation devices for intraoral bone grafts (donor and recipient sites).** In the premolar region of the right maxilla: a corticocancellous graft from the maxillary tuberosity fixed with a mini lag screw. In the incisor region of the right maxilla: lateral augmentation of a sharp ridge with primary implant insertion using a titanium grid fixed by mini screws. Cancellous chips and bone filings harvested by a bone collector from the suction unit are used as a space maker. In the incisor region of the mandible: vertical and transverse augmentation with a corticocancellous block and chips and from the linea obliqua, using a membrane with pin fixation. Second stage implant insertion required. In the premolar and molar region of the right mandible: lateral ridge augmentation with primary implantation using a block and cancellous chips from the mandibular symphysis fixed with microplates

In the recipient site the bone grafts can be anchored by titanium micro screws, microplates, mini lag screws or nails. The use of a membrane appears to give the best results. Perforation of the underlying alveolar bone with a small drill increases the availability of osteogenic cells from the bone marrow, accelerates revascularization and improves osseous union (Fig. 24.2). In severe defects of the alveolar crest it is better to perform bone transplantation and implant insertion in a two-stage procedure. If the implant can be stabilized in the desired position, bone transplants can be used to cover any defects. In all situations a stable fixation of grafted bone on the bone to be augmented is important (ten Bruggenkate *et al.*, 1992). The resorption usually does not exceed 1 mm of height. If the screw head after surgery is on the level of the bone transplant, usually at screw removal only the head of the screw is found exposed. An unloaded healing period of 6 months is recommended (Jovanovic and Spiekermann, 1992).

25 Alveolar Bone Distraction

Johannes Hidding and Joachim E. Zöller

Introduction

Distraction osteogenesis is a technique for bone lengthening introduced by Ilizarov (1989a, b). It has been successfully applied for long bone lengthening in orthopedic surgery.

The first experimental studies with membranous bone were performed in the early 1970s by Snyder, Levine, and Swanson (1973). In the oral and maxillofacial region this technique was carried out experimentally in dogs (Block, Chang, and Crawford, 1996). McCarthy *et al.* (1992) reported the first clinical cases of mandibular hypoplasia treated by distraction osteogenesis.

Expansion or advancement of the maxilla is often required to correct a skeletal deformity and malocclusion. One therapeutic regimen for correction of the alveolar ridge is surgically- assisted palatal expansion in cases of horizontal maxillary deficiency with crossbite (Bell and Epker, 1976; Hidding and Breier, 1997).

In orthognathic surgery correction of malocclusion or open bite by segment osteotomy is routinely carried out. In cases where greater parts of the alveolar ridge are moved in a one- stage operation, complications are more common. These range from periodontal defects to loss of bony segments and teeth (Betts *et al.*, 1995). In edentulous patients the alveolar bone loss can be substituted by autologous bone grafts. With the vertical bone distraction technique of the alveolar ridge, it is possible to elevate segmented parts of the jaws as well as edentulous areas in atrophic regions, as described by Block, Chang, and Crawford (1996). They showed in dogs that bone had formed between the distracted segments, creating an elevated ridge. Sometimes following radical tumor surgery or dentoalveolar trauma, a bony gap of the alveolar ridge results in the need for late or secondary reconstruction. Some patients are satisfied with prosthetic rehabilitation, others ask for immediate surgical correction with bone grafts or implants. For these problems, we use the technique of bone or callus distraction described by Ilizarov (1989a, b).

Technique

In edentulous parts of the mandible after segmental resection in tumor surgery or trauma loss, instead of bone transplantation, reconstruction by vertical distraction can be used (Fig. 25.1). After osteotomy the segmented cranial part of the toothless bony gap of the mandible is mobilized. The survival of this segment is dependent on the preservation of the lingual mucoperiosteal flap. The distractor can then be inserted (see Fig. 25.1) and the bony segment is stabilized for 7 days. The regimen for callus distraction is 0.5 mm, twice each day. Within 15 days a previously estimated vertical increase of 15 mm can be obtained. Four weeks later, mineralization of the new bone can be seen to be starting (Fig. 25.2), as well as reunion of the transported bone in the alveolar ridge. Early mineralization studies suggest that insertion of

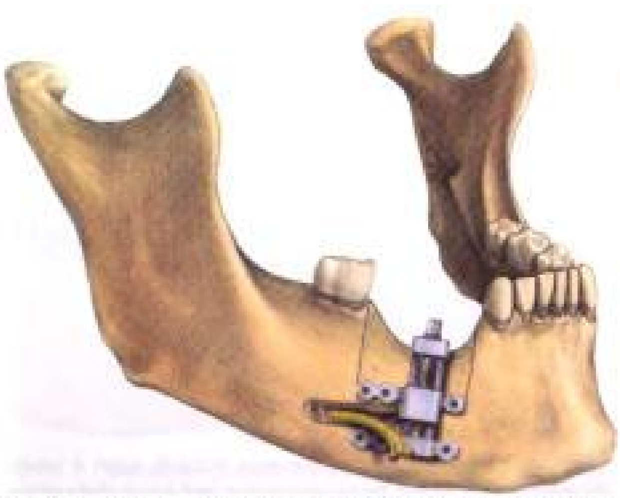

Fig. 25.1 **Osteotomy of the segmental cranial part of the toothless bone.** The distractor has been inserted

Fig. 25.2 **Four weeks after bone distraction, mineralization of the new bone in the distracted gap has begun**

dental implants is possible after 3 months (Yamamoto et al. 1997).

In the tooth-bearing areas of the mandible, vertical bone distraction of the alveolar ridge to transport tooth-bearing segments is also possible. This is used in cases such as a local open bite, because of a vertical undergrowth of the alveolar ridge caused by ankylosed teeth.

The segment with the ankylosed tooth is osteotomized with a Lindemann burr, via a vestibular approach. The lingual cortex is separated with chisels to preserve the lingual mucoperiosteum. The distractor is inserted and the segment stabilized for 7 days (Fig. 25.**3**). An increase of 10 mm is achieved in the segment (Fig. 25.**4**). After 4 weeks the distractor is removed. To prevent relapse a bracket stabilization with an orthopedic wire is performed. During distraction, the vitality of the mobilized tooth remains intact and no damage of neighboring teeth appears. One month after distraction, bony structure and mineralization in the distracted gap region is seen (see Fig. 25.**4**).

Clinical Aspects

Yamamoto et al. (1997) reported stable bone formation in the distraction gap after 3 months . They found new bone in canine maxillas 4 weeks after bridging the distraction gap, and after 8 weeks the border between the original and regenerated bone was difficult to distinguish. Histologically-regenerated bone was visible along with collagen fibers and after 8 weeks, the matured, regenerated bone was visible in the gap, which was filled with a network of lamellar bone. Distraction osteogenesis now provides the possibility for almost unlimited new bone formation. Because of early mineralization, dental implants can be inserted into the new bone after 3 months. In addition to the vertical increase of bone, a simultaneous gain of soft tissue is apparent so, as well as bone transport and osteogenesis, a complete histogenesis of the alveolar ridge can be seen. Vertical distraction is possible to correct an atrophic sharp bony alveolar crest. The surface of the alveolar crest can be smoothed, which is accompanied by a loss of vertical height. Then vertical distraction can elevate the bone again, regaining the height of the alveolar ridge. A broader alveolar ridge is obtained. In a one-stage operative procedure a vertical and a horizontal gain of bone and soft tissue can be produced.

Conclusion

The advantages of callus distraction in edentulous bony gaps are:

- no bone harvesting;
- no donor site morbidity;
- distraction of vital bone;
- less resorption compared to sandwich osteoplasty;
- no infection problems;
- early mineralization of new bone;
- implantology after 3 months; and
- shortening of treatment time.

Additional advantages for distraction of tooth-bearing segments are:

- therapy of local open bite;
- safe blood supply to the segment;
- teeth vitality remains intact; and
- no periodontal problems.

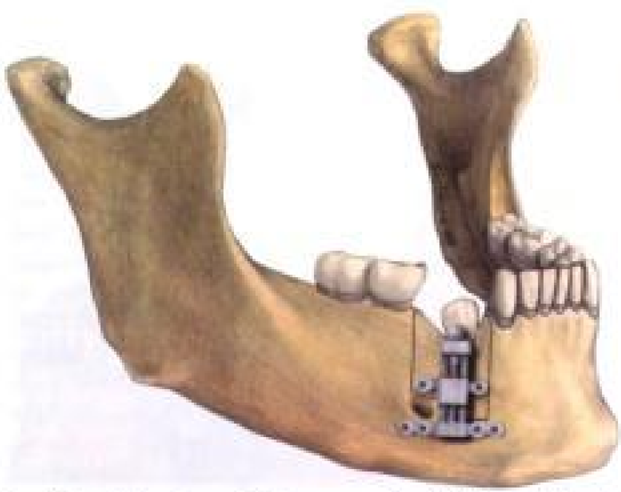

Fig. 25.3 **Osteotomy of the segment, with the ankylosed tooth and insertion of the distractor**

Fig. 25.4 **Mineralization of the new bone is seen 4 weeks after insertion of the bone distractor and bone distraction.** To prevent relapse a bracket stabilization with an orthopaedic wire is performed

26 Mesh Fixation of Bone

Bodo Hoffmeister

Introduction

Different osteosynthesis techniques can be applied to fix bone grafts when reconstructing the mandible. This chapter looks at titanium mesh which, in addition to osteosynthesis techniques described in previous chapters, completes the spectrum of available fixation methods.

Lambotte published an article in 1913, describing the treatment of a median mandibular fracture using a plate, which identifies the basic principles for mesh osteosynthesis. Boyne (1969) first used titanium mesh for mandibular reconstruction, later Hauenstein and Steinhäuser (1977) reported on technical advantages and clinical experiences. The titanium mesh was originally developed for mandibular reconstruction in combination with cancellous bone chips (Boyne, 1969). The idea was to replace the mandible by a U-shaped titanium mesh filled with autologous iliac crest spongiosa (Steinhäuser, 1982; Dumbach and Steinhäuser, 1983; Dumbach, 1985; Dumbach *et al.*, 1994). A range of titanium meshes has been developed, based on those used by earlier workers, and it is available in a selection of different sizes.

Wolff *et al.* (1996) reported on 24 cases of mandibular reconstruction using a fibula free flap with microsurgically anastomosed vascular pedicles. He observed one broken plate and one infection at the osteosynthesis line.

Individual patient requirements determine which size of titanium mesh to use. For mandibular reconstruction, the 2 mm system is the osteosynthesis material of choice. In special cases where free bone of the alveolar crest, or other bone graft, is to be fixed on the mandible to reconstruct the alveolar ridge, the 1.5 mm system is useful (Figs. 26.**1**, 26.**2**).

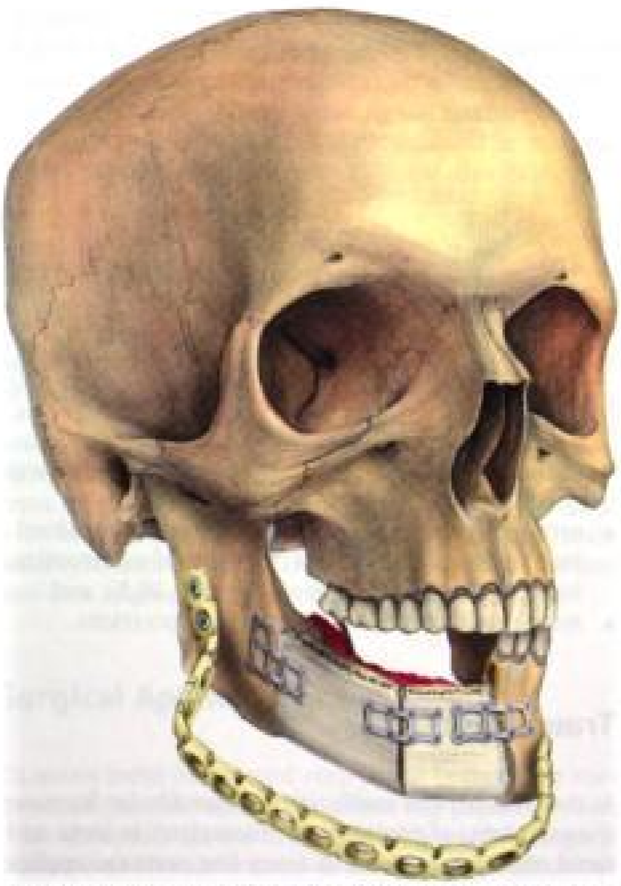

Fig. 26.**1** **Mandible reconstructed by microsurgically anastomosed iliac crest flap using 2 mm titanium mesh.** Note the temporary fixation of the ascending rami during the osteosynthesis of the iliac crest flap

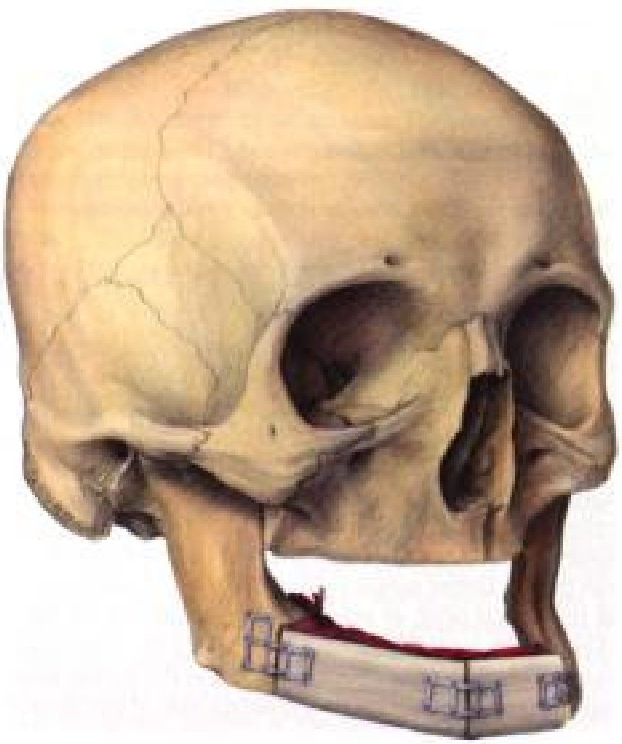

Fig. 26.**2** **Osteosynthesis fixation of microsurgically anastomosed fibula flap to reconstruct the mandible.** This is a case of osteoradionecrosis following irradiation for oral cancer

Fig. 26.3 **Bony defect of the midfacial skeleton due to tumor involvement of the zygoma.** The facial skeleton was reconstructed by using prebent titanium mesh. In such cases there is nearly always an acceptable esthetic and functional outcome

Fig. 26.4 **Titanium mesh fixation after Le Fort I osteotomy in orthognathic surgery.** Titanium mesh plates are easy to bend and easy to fix

Mesh systems are valuable in that they give the surgeon the opportunity to construct a plate to the individual needs of the patient. With a special instrument, the mesh cutter, custom plates can be produced to meet the specific demands presented by the particular part of the facial skeleton to be reconstructed.

Custom-made osteosynthesis plates can satisfy the surgeon's individual needs for different approaches. Excellent results have been achieved using titanium mesh systems in the reconstruction defects of the facial skeleton during tumor surgery. Titanium mesh is ideal for use in the lateral orbit, or other bony structures of the facial skeleton, in interdisciplinary treatments for craniofacial tumors involving the neurosurgeon and the ophthalmologist (Fig. 26.3). This mesh reconstruction of the skeletal parts gives the patients an acceptable esthetic and functional outcome. In interdisciplinary treatment of craniofacial tumors, a mesh system is nearly always used as the osteosynthesis material for reconstruction of the resected bone.

Indications

As well as for reconstructive surgery, particularly of the mandible, mesh fixation of bone is also indicated in other fields of maxillofacial surgery, such as:

- traumatology—repair of bony defects; osteosynthesis in comminuted and multiple fractures;
- orthognathic surgery—fixation of the maxilla after Le Fort I osteotomy (Fig. 26.4); fixation of osteotomized bone segments after genioplasty (Fig. 26.5); and
- reconstructive surgery after tumor operations.

Traumatology

In the treatment of midfacial and mandibular fractures, the usefulness of miniplates or microplates in some midfacial regions is obvious. In a very few cases the application of titanium mesh in different sizes may be helpful. In some cases of severely comminuted fractures of the facial wall of the maxillary sinus, a micromesh can reestablish the normal size of the maxillary sinus. In addi-

Fig. 26.5 **Genioplasty with chin reduction and osteosynthesis using titanium mesh.** Titanium mesh is very easy to bend and may be exactly applied to the individual situation

Fig. 26.6 **Reconstruction of the alveolar crest of the mandible in the frontal region after tumor resection and postoperative irradiation.** Note the fixation of the iliac crest graft. Due to the monocortical application of the screws and mesh osteosynthesis, it is not always necessary to remove the material when titanium dental implants are used

tion, if an osteosynthesis is needed for badly comminuted fractures of other midfacial regions, even in the mandible, the bone pieces generally can be collected and fixed using titanium mesh.The removal of the material can be performed up to 1 year after the operation.

Orthognathic Surgery

The titanium mesh system represents an additional osteosynthesis material that is very useful in orthognathic surgery for fixation of the maxilla after Le Fort I osteotomy. The mesh is easy to bend and very easy to apply. Some surgeons prefer 1.5 mm osteosynthesis systems for maxillary fixation during orthognathic surgery.

In addition to maxillary fixation with titanium mesh, osteosynthesis in genioplasties including chin reduction and chin augmentation can be performed.

Surgical Applications

Titanium mesh has proved very useful because the surgeon can custom-make plates to suit any particular case.

In addition to its use in routine orthognathic surgery, titanium mesh can be used in managing complications such as "bad" mandibular sagittal split. The versatility of the material allows customizing at surgery and application to provide secure fixation of the bone part leading to uneventful healing and an acceptable outcome.

The titanium mesh system can be used to reconstruct the bony continuity of the mandible using microsurgically anastomosed bone flaps, for example from the fibula, the iliac crest, or other sites. The most preferred flap for mandibular bone reconstruction is currently the fibula transplant (see Chapter 29).

The osteosynthesis used is monocortical osteosynthesis as is described in previous chapters. In some cases, parts of the mandible can be fixed before resection, using reconstruction plates to stabilize the ascending ramus and both condylar processes (Fig. 26.**1**). Irrespective of the size and shape of the tumor during resection, this bridging plate device will stabilize the residual mandible. Harvested bone can be put in the gap, trimmed and shaped into the proper position and then fixed using 2 mm titanium mesh with a minimum of four screws at each osteotomy site. After fixation the reconstruction plate has to be removed, then the microsurgical anastomosis can be performed. This surgical procedure results in the proper position of the ascending rami as well as a mandibular shape similar to that of the original.

One advantage which titanium mesh offers over reconstruction plates is that the mesh used as described allows functional loading of the transplanted bone which aids healing and reestablishment of mandibular continuity.

In most cases monocortical osteosynthesis should not hinder the proper insertion of dental implants, when these are necessary. There should be no difficulty in removing the titanium mesh after 1–1½ years, should the patient's prosthetic restoration or dental implants require this (Fig. 26.**6**).

The general principles of mandibular osteosynthesis with miniplates should be followed to avoid pitfalls with these osteosynthesis procedures, in particular:

- be careful not to put titanium mesh around the lower border of the mandible, because strain interaction will lead to plate fractures; and
- avoid sharp edges which could perforate the mucosal layer.

Intermaxillary fixation is not required when using this mesh osteosynthesis technique in mandibular reconstruction.

Conclusion

To summarize, the major advantage of mesh osteosynthesis systems in reconstructive surgery of the maxillofacial region lies in the ability to customize the material, in size and in shape, during surgery. This gives the surgeon the opportunity to perform reconstruction in a moderate amount of time and with reasonable stability.

27 Mandibular Reconstruction with Free, Non Vascularized Bone Grafts

Hans-Dieter Pape and Klaus Louis Gerlach

Introduction

The first free transplantations of autologous bone for reconstruction of the mandible were carried out by Lexer, who, in 1907, used bone from the tibia and, in 1908, part of a rib (Reichenbach and Schöneberger, 1957). Various techniques of reconstruction have since been developed.

The functional integration of a free bone transplant into the local bone structures is of the greatest importance to a successful outcome. This ensures that physiological stress factors can influence the early remodeling of the transplanted bone. The quality of the bone transplant, the stability of bone fixation and the condition of the surrounding soft tissue are critical to the success of transplantation. Experience has shown that the iliac crest is the ideal bone for reconstruction of the jaw. Rib transplants are mainly used as substitutes for the neck and head of the condyle and for reconstruction of children's jaws.

Reconstruction is usually carried out using an extraoral approach. In cases of benign tumors a primary reconstruction directly following resection is possible. This can be done intraorally if the size and location of the tumor allow it. In malignant tumors, bone reconstruction is generally performed as a secondary operation after 1 year free from recurrence.

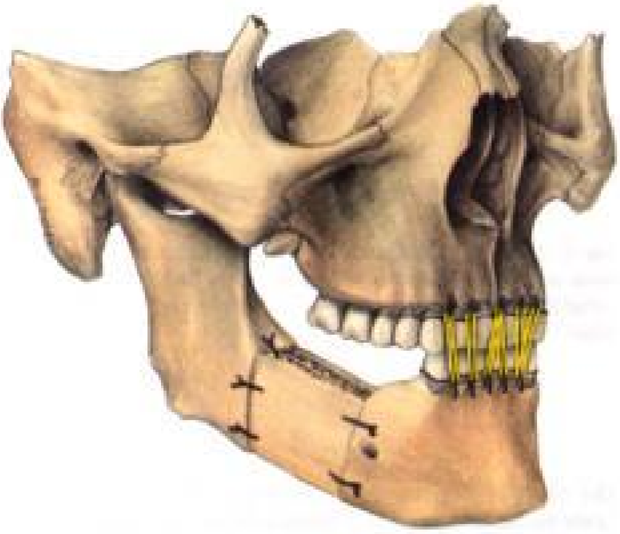

Fig. 27.1 **Wire fixation of the graft and intermaxillary fixation of the mandible**

Technique

For the fixation of an iliac crest transplant, wire was the most frequently used osteosynthesis material until 1975. Even today, parallel or crossed double wiring with 0.5 mm soft steel wire is a reliable method of simple fixation, but it requires intermaxillary fixation for about 8 weeks because of its limited stability (Fig. 27.**1**).

Intermaxillary immobilization is unnecessary if bridging plates are used. This type of plate (e.g. AO, Osteo, Synthes, etc.) has to be fixed to the stumps of the mandible with at least three screws (Fig. 27.**2**). These screws have to be long enough to be bicortical. The plates assure complete stability of even large transplants. However, the large plate systems (Luhr, 1976; Reuther, 1979; Schmoker, von Allmen, and Tschopp, 1982; Raveh 1990) do have the problem of their large size, which results in considerable tension on the surrounding soft tissue, with a risk of dehiscence. Additionally, the revascularization of the transplant is delayed by the large area of contact with the plate. Strong plates have a high degree of inflexibility, which results in an insufficient transfer of function to the transplant. This effect, called 'stress protection,' leads to progressive sponginess of the bone and, if

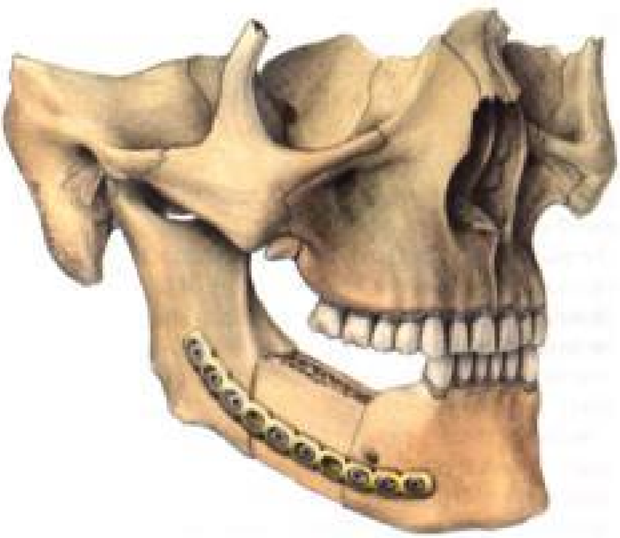

Fig. 27.**2** **Reconstruction of the mandible with a free graft fixed by a compression plate**

Fig. 27.3 **Mandible with a benign tumor in the right molar area with bore holes in resection lines.** Two titanium reconstruction miniplates adapted and provisionally fixated on both sides

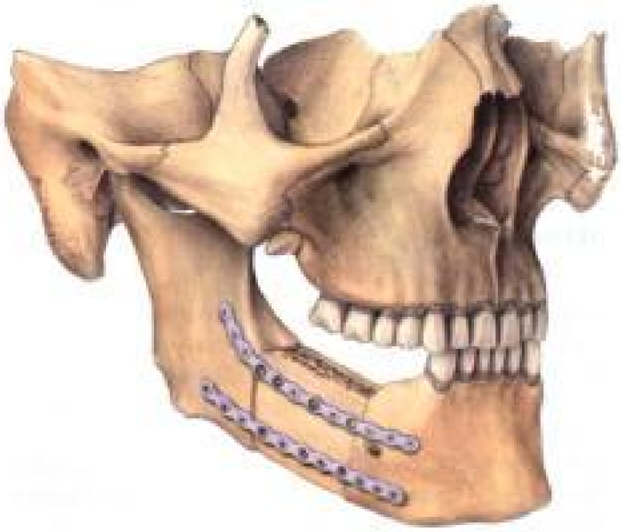

Fig. 27.4 **The same mandible as Fig. 27.3 after resection of the tumor segment.** Reconstruction with a free bone graft fixated with two titanium reconstruction miniplates

the plate is not removed, after 5–6 months to marked atrophy. Early removal is necessary so that the bone can reconstitute itself under normal physiological loads.

The successful use of miniplates in fracture treatment led to the development of a titanium reconstruction miniplate, which has the same small size as the fracture plate but an increased thickness of 1.27 mm (Schmid and Pape, 1991; Pape *et al.*, 1993; Pape, Gerlach, and Schippers, 1994). It is necessary to use these as double bridging plates. In all cases of primary reconstruction, the titanium reconstruction miniplate should be adapted and temporarily screwed to the surface of the unresected mandible, prior to ablation. If the length of the transplant is identical with the length of the resected bone, it is possible to reconstruct the mandible in its original anatomical form (Figs. 27.**3**, 27.**4**). It is recommended that the plate be fixed at each end with at least three and not more than five screws. The screws are of the same size as those used for fracture plates, but they should, of course, be longer for bicortical fixation. For the fixation of the free bone transplant it is sufficient to use one screw in every second plate hole.

In those cases where only a small part of the condylar head is available for fixation, narrow reconstruction plates are particularly useful (Fig. 27.**5**). If the entire ramus including the articular head has to be replaced, the titanium reconstruction miniplates should not simply be fixed to the stump of the jaw with the adjoining transplant, but should be long enough to fix nearly the entire length of the transplant (Fig. 27.**6**). This is not only to increase the stability of the transplant during the process of rebuilding, but also to ensure the transfer of functional stimuli to the whole transplanted bone. Clinical experience has shown that, even in such difficult cases, intermaxillary fixation is not necessary.

The application of two titanium reconstruction miniplates confirms the assumption that the early transfer of function to the transplant reduces the risk of atrophy and encourages stability (Pape, Gerlach, and Schippers, 1994).

As an alternative to fixation with plates, a preformed tray of titanium mesh can be used. This is also fixed with three screws to the stumps of the mandible and, because of its special shape, can be filled with cancellous and pieces of cortical bone (Fig. 27.**7**). Within 3–6 months the bone fragments will rebuild the missing part of the mandible in the form of the titanium tray (Boyne, 1969; Dumbach *et al.*, Dumbach 1994). Removal of the mesh is complicated as some areas become integrated with the bone.

If narrow bone transplants can be placed on the buccal side of a mandible stump, lag screw fixation is a good alternative. In such cases the outer cortex of the stump has to be removed. Two lag screws are used to achieve a stable fixation for the transplant to the lingual cortex of the stump. The reconstruction of the articular surface with a rib transplant is an example of this technique (Fig. 27.**8**).

No matter what method of osteosynthesis is used, the reconstruction of the mandible requires special care. The transplanted graft should not have any sharp bone edges under the surface of the mucosa. A direct and good contact between the graft and the stumps of the mandible is always necessary. If there are any spaces between the buccal cortex caused by convex bending of the graft they should be filled with cancellous chips. Sufficient stability of the graft must be the goal whenever any kind of osteosynthesis is used.

28 Mandibular Distraction Osteogenesis Using Intraorally Applied Devices

Konrad Wangerin and Henning Gropp

Introduction

McCarthy *et al.* (1992) developed a miniaturized distraction device for hand surgery and subsequently used this as an extraorally applied device in maxillofacial surgery, to lengthen the malformed mandible. A titanium device that could be used intraorally was quickly developed, to avoid cheek scars and to enable invisible distraction of the mandible (Wangerin and Gropp, 1994). After using it first in adolescents (Wangerin and Gropp, 1995), it was then used in adults (Wangerin et al., 1996). Nowadays unilateral and bilateral mandibular deficiencies of the horizontal and vertical ramus can be corrected in infancy, childhood and in adults using different intraoral distraction devices (Wangerin and Gropp, 1997, Gropp et al., 1998).

Appliances

Horizontal Mandibular Distraction Device

The parts of the appliance are each made from one piece of titanium to avoid welded joints. The device is constructed as an intraoral distraction chamber and consists of a rectangular distraction cylinder within a distraction bar. There are two L- and T-formed miniplates on each end of this appliance. Once these plates have been bent to the contour of the bony surface of the mandible, the fixation of the device is by 5 mm monocortical 2 mm screws (Fig. 28.1). Horizontal 20 mm and 25 mm distraction devices for the left and the right side of the mandible are available.

Angled Horizontal Mandibular Distraction Device

This appliance is similar to the horizontal distraction device. The difference is the angled miniplate at the end of the distraction bar (Fig. 28.2), which is necessary for parallel bilateral mandibular distraction without changing the intercondylar distance. The direction of distraction is provided by the flexible joint, giving a small backward movement, and by the mandibular advancement. The parallel fixation of both appliances is possible with a special intraoral positioning bow which is being fixed occlusally.

Vertical Mandibular Distraction Device

Each part of this appliance is also made from a single piece of titanium to avoid welded joints. The distraction system is closed and consists of a rectangle distraction chamber and a distraction bar with L- and T-formed miniplates on both ends. The chamber contains a gear for changing the distraction direction through 90°, which is connected with the universal joint of the activation pin. Once the miniplates have been bent, the fixation of the device to the mandible by 5 mm monocortical 2 mm screws is possible (Fig. 28.3). A vertical 25 mm distraction device for the left and the right side of the mandible is available.

Fig. 28.1 **Horizontal mandibular distraction by fixation of the horizontal 20 mm distraction device parallel to the occlusal plane**

Fig. 28.2 **Horizontal mandibular distraction in adults.** The angled posterior miniplate makes possible parallel distraction of both horizontal rami for elongation of the short mandible, without affecting the intercondylar distance. In addition, the use of a positioning support is necessary. The distraction device is applicated on the outer cortex of the ascending ramus of the madible

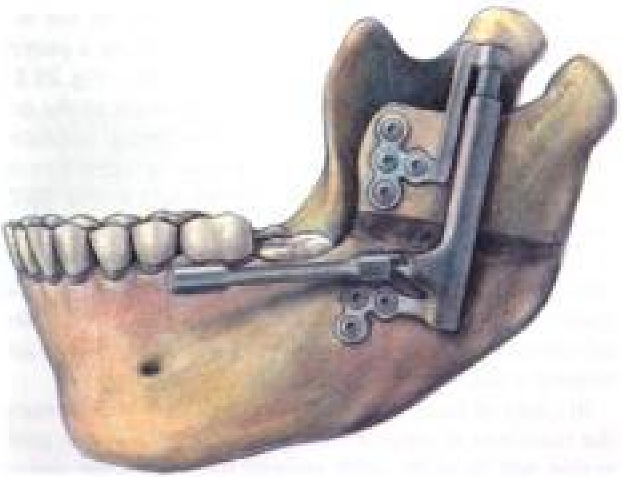

Fig. 28.3 **Deficiencies of the vertical mandibular ramus are corrected by the vertical 25 mm distraction device.** This contains a transaxle in the distraction cylinder and a universal joint for the safe location of the activation pin in the vestibulum

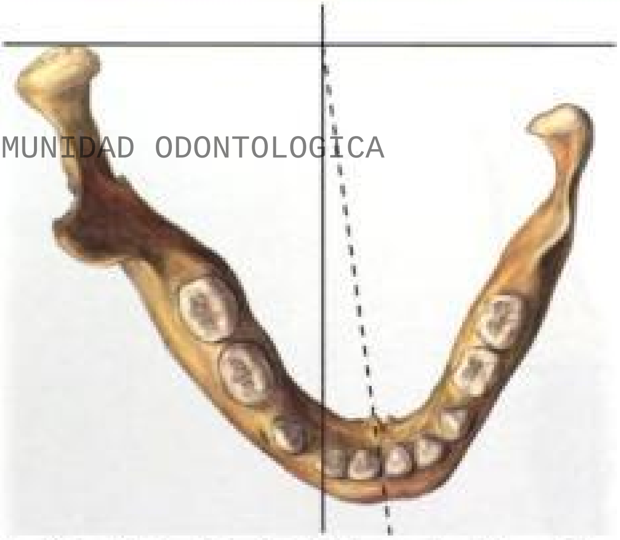

Fig. 28.4 **Unilateral hemifacial microsomia with mandibular midline deviation to the malformed side**

Fig. 28.5 **Technique for affecting the transverse dimension.** This shows an extended device with curved miniplates for lateral mandibular extrusion with a three-cornered bony gap

Indications

Indications for horizontal distraction of the mandible are unilateral or bilateral horizontal ramus deficiencies, both in the growing skeleton and in adults. The 20 mm horizontal device in infancy and the 25 mm device in childhood and in adults are preferred.

This method can be used in mandibular malformations with obstructive sleep apnea, for example in craniofacial microsomias. In Treacher Collins syndrome and Robin deformity the mandible can successfully be elongated by the horizontal distraction device.

In unilaterally malformed mandibles with soft tissue hypoplasia (Fig. 28.**4**) the mandibular distraction can be combined with increasing the transverse dimension by extending the device and curving the plates (Figs. 28.**5**, 28.**6**).

Class II malocclusions are the main indication in adults. Gradual mandibular advancement seems to cause less of a problem with the mobile temporomandibular joints with disc damage than with the bilateral sagittal split osteotomy. However, there must be parallel bilateral distraction with angled devices using an intraoral positioning bow, fixed by a mandibular dental splint.

Indications for vertical mandibular distraction are seen in cases of vertical ramus deficiencies. There is no indication in infancy but there is in childhood, in cases of craniofacial microsomia and Treacher Collins syndrome. In adults, the ascending ramus can be unilaterally elongated, in cases of avascular necrosis of the mandibular condyle and in cases of malpositioned mandibular condyles after bilateral sagittal split osteotomy. It may also be valuable in adults as adjunctive treatment for asymmetries caused by progressive condylar resorption.

Technique

All operations are done under general anesthesia using nasal intubation. After injection of vasoconstrictors, the mucosa is opened as for a sagittal split osteotomy. The buccal surface of the mandible is exposed subperiosteally. The device is then temporarily fixed by two monocortical 5 mm screws (2 mm diameter) on both sides of the planned osteotomy.

The direction of distraction must be controlled carefully. If the distraction cylinder lies parallel to the occlusal plane, the result after distraction will be a purely horizontal mandibular advancement (see Fig. 28.**1**). Where the distractor is positioned at an angle to the occlusal plane, the result will be a mandibular advancement and, in most cases, a tendency for an open bite to be produced. In unilateral oblique elongation (Fig. 28.**7**) there is mandibular autorotation and advancement with an open bite in both molar regions. In vertical distraction, there is a nonocclusion in both lateral occlusal planes. The direction of distraction will be determined preoperatively by cephalometric analysis to avoid an additional mandibular advancement.

In cases of malformations with soft tissue deficiency, the transbuccal approach for fixating the device is preferable and in adults with normal soft tissue the use of the angled screwdriver for intraoral fixation of the device is favored. All drill holes are made to suit the predetermined position of the device and the osteotomy line is marked with drill holes. The screws and the device are then removed and the complete osteotomy is performed with saw, drill and chisels, preserving tooth buds and the alveolar nerve.

To avoid exposure of the lingual mandibular perios-

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Fig. 28.8 Intraorally applied callus distractor with microscrews

teum, the last step of the osteotomy is to complete the fracture in this region. After total mobilization of the osteotomy the device is placed and fixed with screws using all holes. In the holes used for initial location, emergency screws should be used. Wound closure is done with resorbable sutures.

The distraction starts on the third or fourth day after the operation. The daily distraction distance is 0.8 mm to 1.2 mm, which requires two to three left turns in one or more fractions. Antibiotics are given during the operation and continued through the fifth day.

The technique can be performed on patients aged from about 3 up to around 50 years. The length of distraction that is possible is from 5 mm to 25 mm for unilateral, bilateral, horizontal and vertical cases (Wangerin and Gropp, 1997). For the intraoral callus distraction a distraction device with the use of microscrews has been developed recently (Hoffmeister et al., 1998) and good results was reported (Fig. 28.8).

Complications

Wangerin and Gropp (1997) saw three temporary neurosensory deficiencies and in one patient pain. There was no permanent neurosensory deficiency but in two cases the distraction vector was not correct and was adjusted at the end of the procedure by using elastic bands, to close an open bite.

Premature ossification was seen in one patient with vertical distraction and distractor fractures in two patients. During the prototype period one infection occurred after secondary distraction in a patient with a horizontally-elongated microsomia. During distraction, local pain was seen in four patients and temporary neurosensory deficiencies in five, but these resolved without permanent changes.

Preoperative Diagnostics for Graft Shaping

The reconstruction of the lower jaw requires that the outer contour of the mandible is in a correct anatomical relation to the maxilla (the maxillomandibular relation) and is satisfactory for the esthetic result. The height of the graft only plays a secondary role in esthetics, but it is important for subsequent rehabilitation of the masticatory function with endosseous implants.

As part of preoperative preparations for a mandibular reconstruction, a lateral cephalometric X-ray and a computerized tomographic image are taken in a transverse plane, caudal to the root tips of the mandibular teeth. The resulting images are produced at a 1:1 scale. The mandibular angle and the ascending mandibular ramus are marked on the lateral cephalogram or corresponding markings of the mandible made on the computerized tomographic images. Patterns are then produced from transparent plastic material. After sterilization, these templates can be used during surgery for the osteotomy and for contouring the fibula graft without separating the pedicle and serve as a reference in two planes. This ensures the shortest period of ischemia for the flap. The osteotomy cuts are placed on the outer lateral surface to avoid a shortening of the graft.

Stereolithographic models are helpful to determine graft length, for the number and localization of the osteotomy cuts, and for the special alignment needed for reconstruction of midfacial defects. A template, which corresponds to the required graft, is fabricated for bone shaping. To shorten both the operation and the ischemic time, miniplates can be bent simultaneously or prior to surgery.

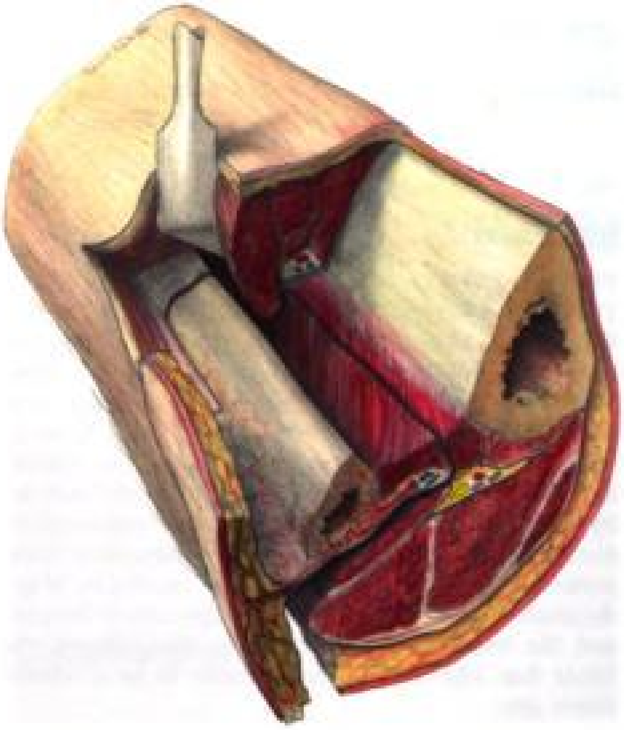

Fig. 29.2 **Schematic drawing of the elevation of a combined osteocutaneous fibula flap.** The septocutaneous perforators may run through the septum or as musculocutaneous perforators through the flexor hallucis longus and soleus muscle

Technique

The lateral approach described by Gilbert (1979) gives easy access to the donor site. The location of the fibula allows two teams to work simultaneously. A tourniquet is used. After palpation of the fibula, the bone is outlined and the peroneal nerve that passes 1–2 cm below the fibula neck is marked on the skin. The skin incision is placed on a straight line between the fibula head and the epicondyle of the ankle (Fig. 29.2). In case of an osteocutaneous fibula flap, the skin paddle to be used is designed in a fusiform shape over the posterolateral aspect of the fibula and centered near its midpoint. After incising the skin, the subcutaneous tissue and the fascia overlying the peroneus longus and brevis muscle, the anterior skin margin is reflected to expose the posterior intermuscular septum. If septocutaneous vessels are not identified, musculocutaneous vessels derived from the peroneal artery and perforating the soleus muscle must be included when raising the posterior part of the flap. Access to the fibula is gained along the intermuscular fascia, taking care not to violate the septocutaneous perforators. Dissection is continued along the anterior aspect of the fibula, retaining a cuff of muscle a few millimeters thick on the bone to protect the periosteal blood supply to the fibula. After retraction of the peroneus longus, peroneus brevis and extensor hallucis longus muscle, the anterior tibial artery and vein can be identified in the anterior compartment. Further dissection along the medial aspect of the fibula allows exposure of the interosseous membrane, which is incised. For posterior dissection, the posterior incision around the skin flap is made to expose the fascia of the soleus muscle and to identify the septocutaneous perforators. Preserving the posterior intermuscular septum, the soleus and flexor hallucis muscle are retracted. After reflecting the periosteum, the fibula is sectioned proximally and distally, using an oscillating saw. The osteotomized fibula is retracted laterally; the peroneal artery and vein are identified and ligated distally. The vascular pedicle is dissected, up to the bifurcation with the posterior tibial artery and vein, by transecting the flexor hallucis longus muscle, leaving a small cuff of muscle on the fibula bone. After reflecting the periosteum from the outer and inner cortex, the straight fibula bone graft can be contoured by wedge osteotomies, using an oscillating saw and rotating burrs (Schmelzeisen, Neukam, and Hausamen, 1996).

Graft Fixation

There are several options for vascularized fibula bone fixation, including interosseous wiring techniques, a single large plate for rigid internal fixation that spans all osteotomy sites, external fixation, and miniplates.

It is difficult to stabilize a fibula graft that has been osteotomized several times, with intraosseous wires alone. There is a need for additional forms of fixation. A large plate, which spans all osteotomy sites, offers rigid fixation to a fibula graft that has been repeatedly osteotomized, and to the mandibular stumps. However, graft shaping is limited because the large plate predetermines the contour of the flap. Furthermore, a large plate adds bulk to the external contour of the graft.

Miniplates have been used in the treatment of facial fractures and provide adequate fixation without the need for additional measures such as maxillomandibular fixation (Champy et al., 1977; Gerlach *et al.*, 1982). There are different plate types available (straight, L-shaped, Y-shaped, H-shaped etc.) that can fix each osteotomy site. Two to three plates are placed on the outer surface and the lower border of the graft and jaw stumps, without stripping the periosteum at each osteotomy site, or at the graft stumps (Figs. 29.**3**, 29.**4**). Self-tapping, monocortical screws allow rapid placement and do not compromise the free graft to a critical degree (Hidalgo, 1989). Miniplates provide sufficient stability and require no additional form of fixation to prevent torsional instability. Miniplates are easily contoured for each osteotomy site. Therefore, they offer excellent fixation, without interfering with the sequence of osteotomies for shaping grafts required to achieve the symmetric contours of the reconstructed midface or mandible (Figs. 29.**5**–29.**7**).

Miniplates compromise the vascularized bone least, because they need only a small layer of cortical bone for monocortical screw fixation, thus leaving the periosteum and muscular attachment largely intact. They provide sufficient stability for early functional loading of the graft and to maintain the required contour of the bone. About 3 to 4 months after bone grafting, the plates can be removed if necessary, and endosseous implants can be inserted for later oral rehabilitation. However, there is no real need for miniplate removal, because the monocortical screws do not interfere with dental implants in most cases. Simultaneous implant installation into the fibula during maxillary or mandibular reconstruction is possible on the basis of blood supply to the graft. However, proper implant placement and angulation is hard to achieve. There is no essential reason to plan endosseous implantation as a primary procedure, except for smaller defects up to 3–4 cm in the lateral aspect of the jaws. Secondary implantation after pretreatment planning is the optimal way to achieve the best result, by placing implants strategically in the best position and angulation to restore occlusal and masticatory function (Hidalgo, 1989).

Fig. 29.**3** **Graft shaping and stabilizing in the lateral view.** The fibula graft is shaped by several osteotomies in the subperiosteal plane to precisely duplicate the contour of the inferior border of the mandible. The cuts are planned in such a way that the pedicle is later located lingually of the mandible graft. Miniplates in two planes are typically placed on the facial aspect of the mandible graft

Fig. 29.**4** **Graft shaping and stabilizing in the frontal view of the mandible**

Fig. 29.5 **Lateral grafts.** One osteotomy is performed to form the angle of the mandible. In most cases the body of the graft requires one more osteotomy to duplicate the horizontal ramus of the mandible. The segments are fixed by miniplates in two planes

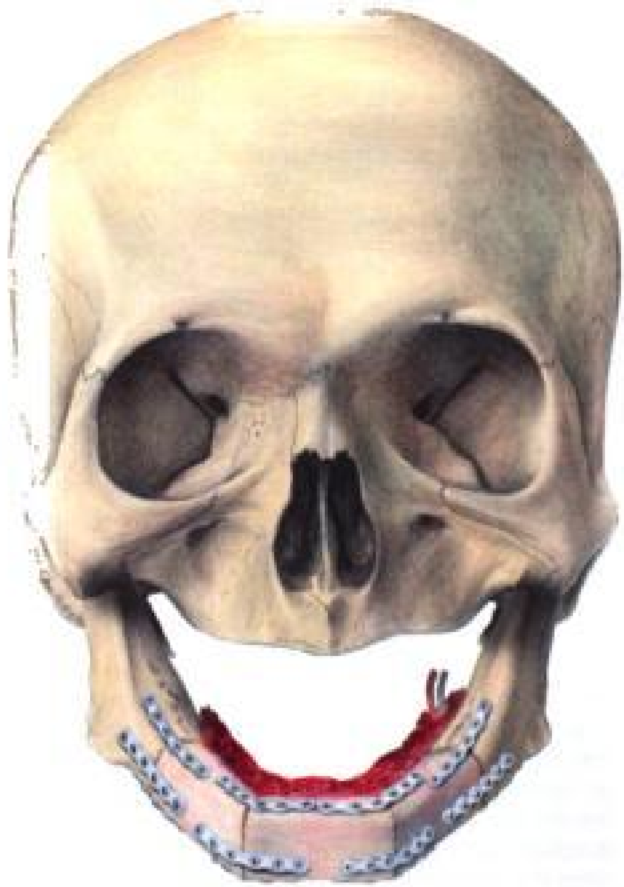

Fig. 29.6 **Anterior grafts.** These consist of a central segment and two lateral segments which may need a further osteotomy on both sides during the graft-shaping process, if the mandibular defect extends to the angle of the mandible. The graft is fixed to the mandibular stumps and the osteotomies are stabilized by miniplates in two planes. Microvascular anastomoses are performed after shaping and fixation of the graft is complete

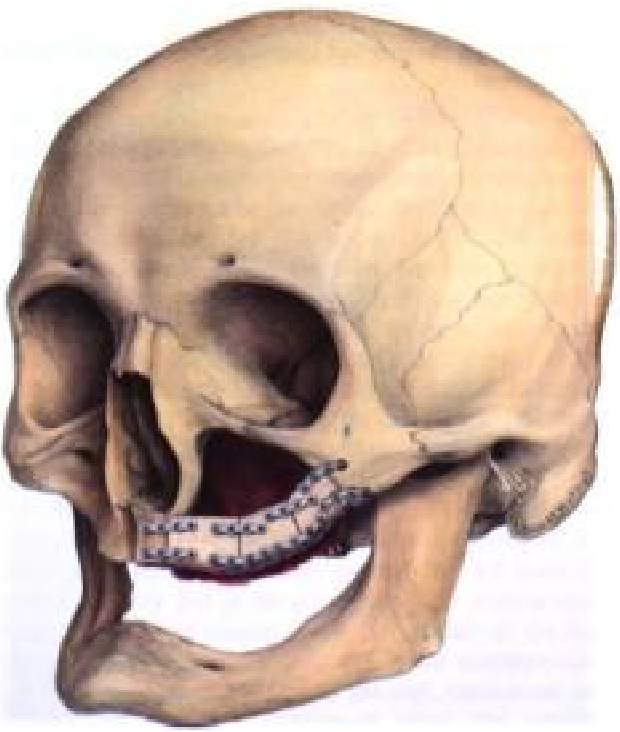

Fig. 29.7 **The fibula is shaped by several osteotomies in the subperiosteal plane to duplicate the alveolar process of the maxilla.** The cuts are planned so that the pedicle is later located laterally to the maxillary graft. Miniplates in two planes are fixed by monocortical screws to the maxillary graft

30 Microsurgical Anastomosis of the Scapula Bone

Rainer Schmelzeisen and Friedrich W. Neukam

Introduction

The scapula region offers the unique possibility of allowing the harvest of one or two soft tissue flaps in combination with a vascularized bone graft. Different aspects of the flap can be mobilized independently from each other, yet vascularized via one pedicle. Since the medial aspect of the scapula is rather thin and often has to be placed at the upper border of the mandible, the bone graft is frequently not suitable for insertion of dental implants. The skin of the scapula region offers a good color match with that of the head and neck area and has the added advantage that it is also thin and pliable.

Anatomical Considerations

The vascular supply of the scapula region is derived from the subscapular artery, which divides into thoracodorsal and circumflex scapular artery 1–2 cm below the axillary artery. The circumflex scapular artery passes through the triangular space bordered by the teres major and minor muscles and by the long head of the triceps muscle. The artery supplies the infraspinatus muscle and the lateral border of the scapula at the proximal aspect of the bone. The inferior third of the lateral border of the scapula is vascularized by the angular branch of the thoracodorsal artery (Fig. 30.1).

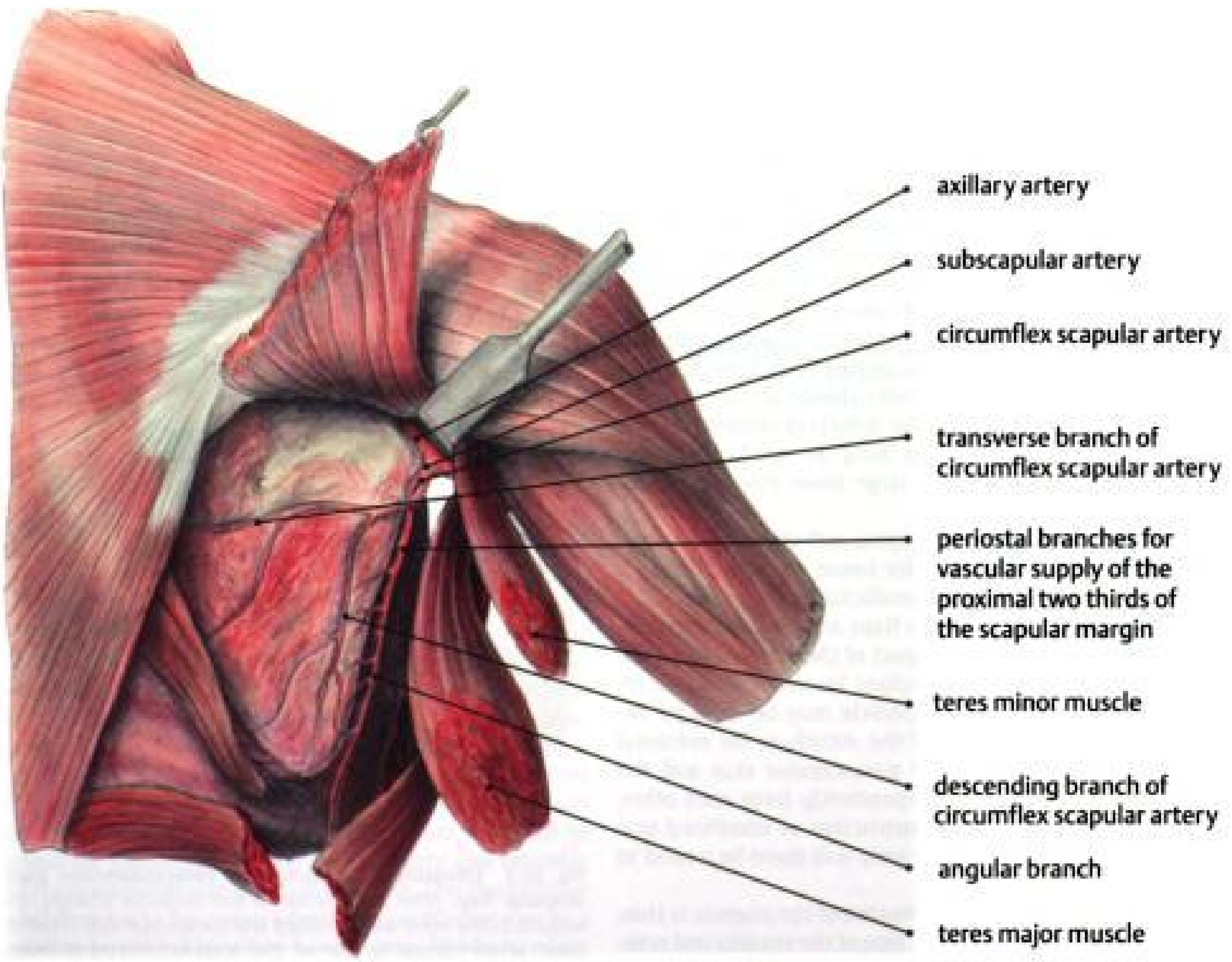

Fig. 30.1 **Vascular supply of the subscapular artery system.** (1) axillary artery, (2) subscapular artery, (3) circumflex scapular artery, (4) thoracodorsal artery, (5) transverse branch of circumflex scapular artery, (6) descending branch of circumflex scapular artery, (7) periosteal branches for vascular supply of the proximal two thirds of the scapular margin, (8) angular branch, (9) teres major muscle, (10) teres minor muscle, (11) long head of triceps muscle

After it has passed through the muscular triangle, the circumflex scapular artery divides into a descending cutaneous branch, the parascapular flap, and a transverse cutaneous branch, the scapula flap (Fig. 30.2).

Harvesting

For harvesting a combined osteocutaneous flap, the parascapular orientation of the soft tissue pedicle offers a safe vascular supply.

For harvesting the bone, the teres major muscle must be cut at the scapula tip. However, some muscular attachment has to be left on the bone to avoid interference with the periosteal blood supply. In general, it is sufficient to harvest 2–2.5 cm from the lateral border to match the height of the mandible. The inferior third of the scapula is nourished by the angular branch of the thoracodorsal artery. This autonomous vascularization does not allow an osteotomy if it is necessary to bend the bone graft (Fig. 30.3). The disadvantage of the soft tissue pedicles of the scapula region, in common with most free flaps, is that there is no sensory supply.

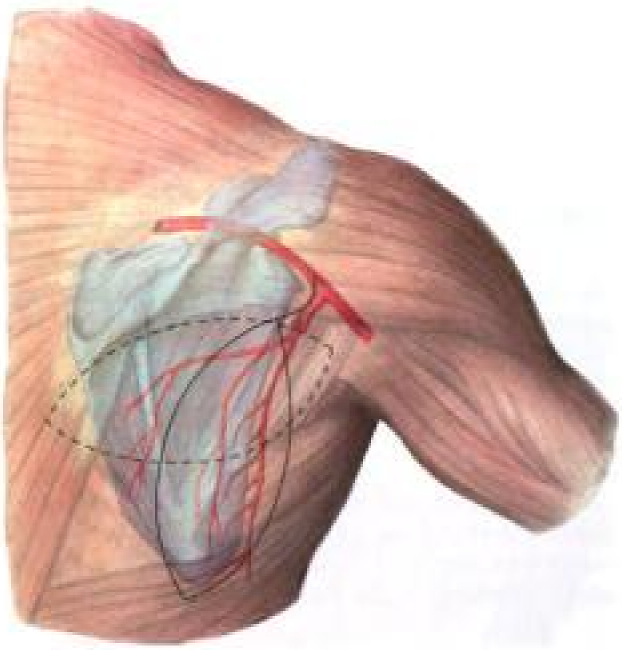

Fig. 30.2 **Schematic drawing showing the relationship of the scapula and parascapular flap below the transverse branch, and the access of the descending branch**

Indication

The scapula region offers unique opportunities for reconstruction of skin, bone, subcutaneous tissue and, especially, combinations of bone and soft tissues. Among all flaps derived from the head and neck area, the texture and color of the skin at the scapula region almost perfectly match the texture and color of the facial skin. Although the skin is relatively thick, it is not as bulky as that of myocutaneous grafts, or free flaps from the iliac crest. In general, scapula grafts should always be considered for complex soft tissue defects or combined bone and soft tissue defects, as long as neither massive volume augmentation nor large bone volume are required.

Isolated de-epithelised scapula soft-tissue grafts may also be used and are ideal for tissue augmentation, for example in patients with hemifacial microsomia.

Combined osteocutaneous flaps are suitable for reconstruction of the posterior aspect of the mandible and the ascending ramus, when implant insertion is not a requirement. The soft tissue pedicle may be used for reconstruction of the floor of the mouth or for extraoral lining. As the scapular and parascapular skin and the bone can be mobilized independently from each other, the flaps are ideal for reconstruction of combined oral and extraoral defects. Only rarely will there be a need to harvest bone grafts alone.

As bone of the medial extension of the scapula is thin, it is often used for reconstruction of the maxilla and orbital floor. The soft tissue pedicle then allows a separation into different functional units, such as the nasal and oral cavity and the maxillary sinus.

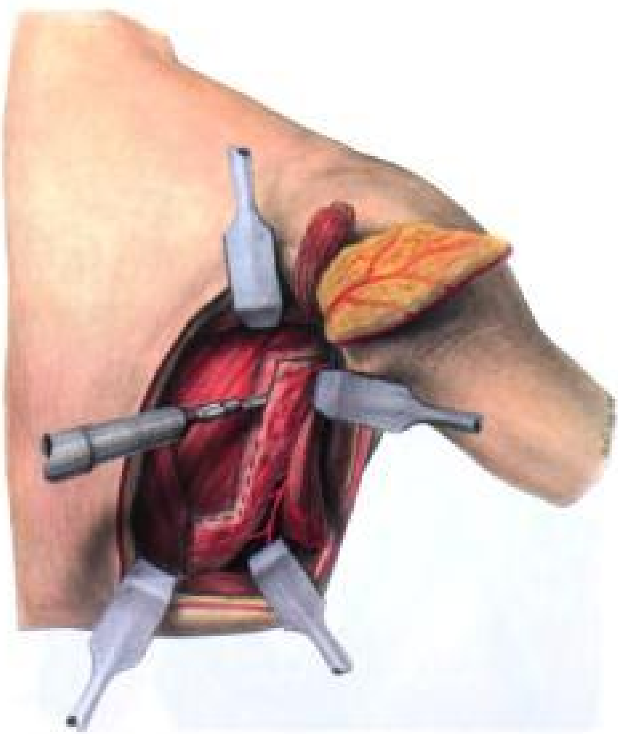

Fig. 30.3 **Elevation of a combined osteocutaneous parascapular flap.** After preparation of the muscular triangle, the vessels to the bone are identified and a muscular cuff must remain at the lateral border of the scapula. The teres major muscle is dissected and the lateral border of the scapula is osteotomized

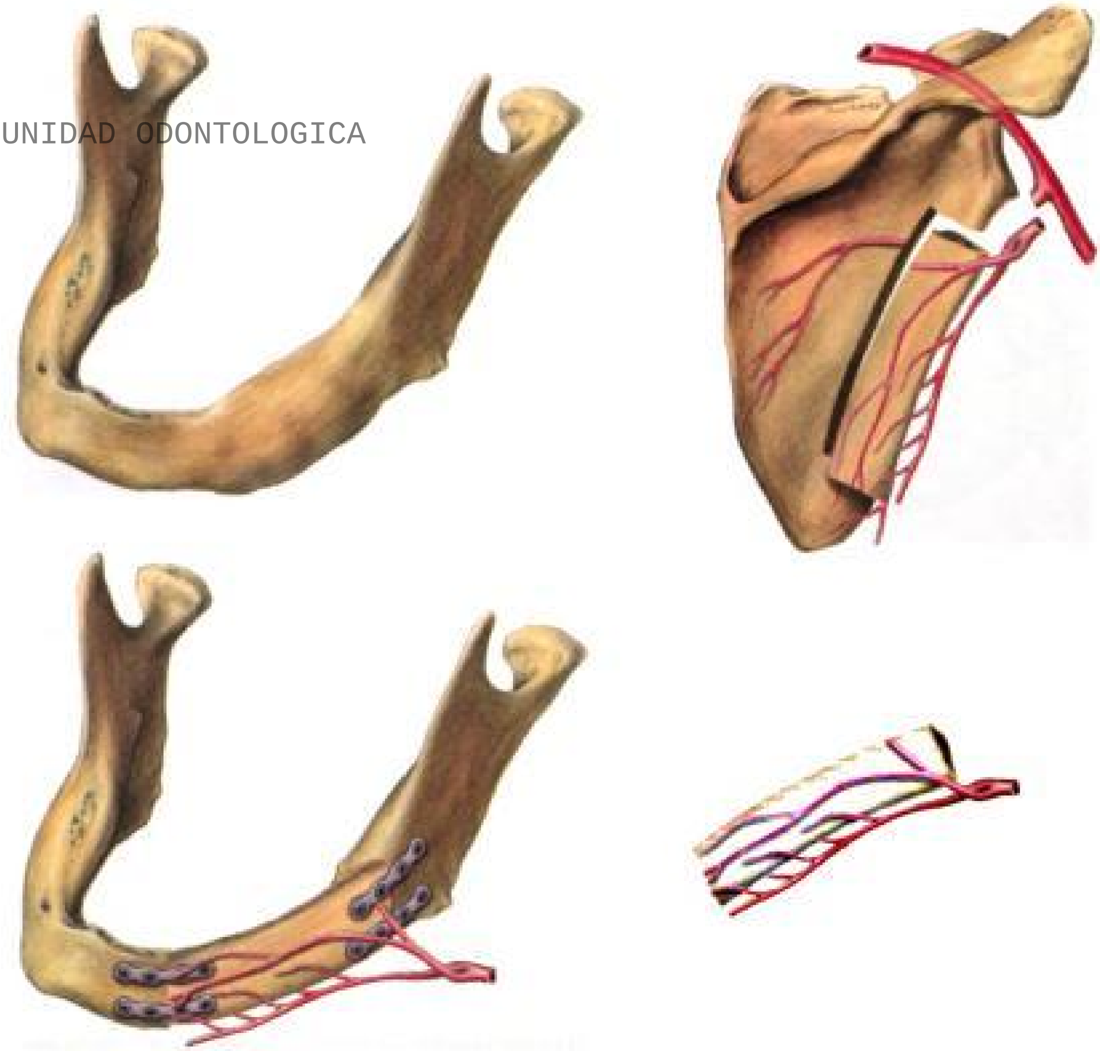

Fig. 30.4 **If the mandibular defect and the recipient vessels are on the same side, the scapula is harvested from the contralateral shoulder.** This allows the vascular pedicle to be located in the angle of the mandible

Mandibular Reconstruction

In every microsurgical reconstruction, preparation of suitable vessels at the recipient site in the neck has to be performed before flap harvesting is begun. The facial vessels of the ipsilateral side are often suitable. In defects with suitable ipsilateral recipient vessels the osteocutaneous scapula graft is harvested from the contralateral side (Fig. 30.4). The residual stump of the mandible first has to be returned to its original position. In situations where the ascending ramus is still present, it has to be prepared, mobilized and moved inferiorly and laterally, after resection of any residual scarring. The mandibular borders have to be prepared with an oscillating saw or a rotating burr until bleeding bone is seen. The bony edges may be osteotomized in an oblique manner to create a large contact surface for the graft, which improves healing between the residual mandibular stumps and the bone graft.

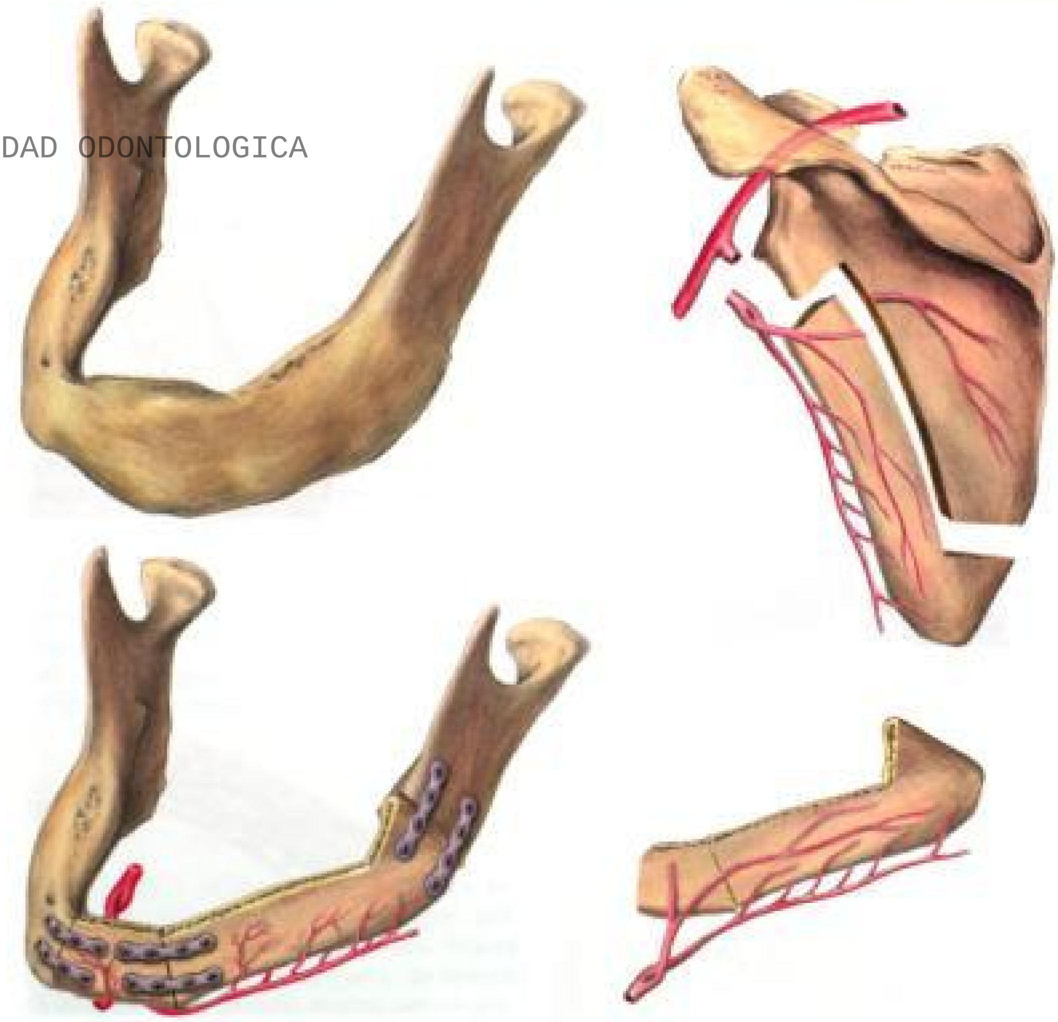

Fig. 30.5 **If the vessels are located on the side contralateral to the mandibular defect, the ipsilateral scapula may be more suitable for vascular anastomosis to the opposite neck**

If suitable ipsilateral vessels are not available, contralateral vessels must be identified (Fig. 30.5). To allow sufficient mobilization of the recipient arteries, the external carotid artery may be ligated cranially. Then, for example, the facial artery can be mobilized almost to the midline of the neck.

As the vascular pedicle in general must be orientated towards vessels in the angle of the mandible, the thicker lateral aspect of the scapula often becomes the inferior border of the new mandible. In patients with an intraoral soft-tissue deficit the soft-tissue pedicle is located medially and inferior to the scapula bone and therefore has to be elevated and trimmed. It is sutured into the defect with minimal tension. Then the bone is fixed into position with miniplates and monocortical screws. When the residual segments are osteotomized obliquely to enhance the bony contact area, the screws may pass through the thin scapula bone graft and the residual stump of the mandible and act as lag screws.

In general, two miniplates are placed with a minimum of two screws per segment. It is not necessary to remove the periosteum before fixation of the miniplates. Lag screws alone do not provide sufficient stability for bone graft fixation.

In predominantly extraoral soft-tissue defects the bone is inserted first and then the cranial margin of the soft tissue flap is inserted. Final fixation of the flap is performed after vascular anastomoses are completed. Then the extraoral flap is sutured tightly into position.

If the ascending ramus including the condyle has to be reconstructed, the tip of the contralateral scapula can be shaped to act as a new condylar head. The vascular pedicle is then at the inner aspect of the bone graft, pointing towards the vessels in the mandibular angle.

Fig. 30.6 **Combined soft tissue and bone defect following complete maxillectomy.** After Cornelius Ketel, *Portrait of a woman aged 56*, 1594, Foundation Museum Thyssen Bornemisza, Madrid

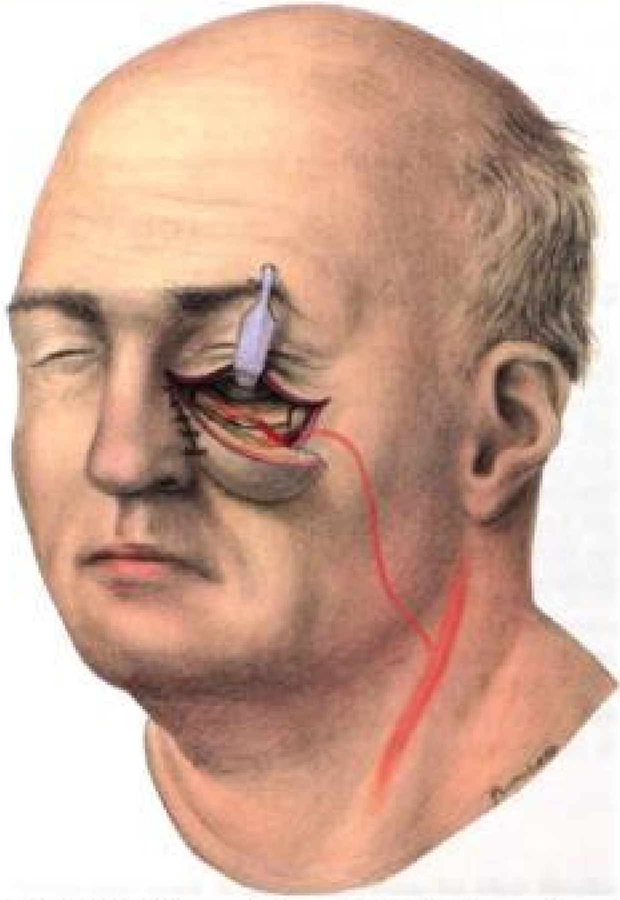

Fig. 30.7 **Soft tissue and bone defect following resection of a maxillary carcinoma.** After Jan Polack, *Portrait of a Benedictine abbot*, 1484, Foundation Museum Thyssen Bornemisza, Madrid

Reconstruction of the Maxilla and Midface

Flaps from the scapula region are ideally suited for reconstructing soft tissue and bone areas in the midface.

In simple maxillary defects it may be possible to reconstruct aspects of the nasal mucosa to create a layer towards the nasal cavity and the maxillary sinus. Then the flat scapula bone is fixed securely to residual aspects of the zygoma. The bony contact between the residual maxillary bone and the bone graft should be as extensive as possible, to allow good bone healing in that area. The soft tissue then can be used to create the oral lining. In later surgical procedures, an additional bone graft can be fixed to the scapula bone to form a new alveolar process suitable for the insertion of dental implants (Fig. 30.**6**).

It is not always possible to position the thicker lateral border of the scapula to form the alveolar process in the maxilla, because care must be taken for a tensionless vascular anastomosis to submandibular recipient vessels. For that purpose the marginal branch of the facial nerve is identified and protected using a paramandibular incision or subfacial preparation in the typical manner. Preparation is continued on the lateral surface of the masseter muscle and a tunnel is created towards the maxilla. Care has to be taken to enlarge the tunnel to avoid compression of the vascular pedicle in the postoperative period.

The superficial temporal vessel has proven not to be very useful for vascular anastomosis, because of the thin and fragile superficial temporal vein.

Postoperatively, the subcutaneous volume of the scapula skin graft may have to be thinned.

For lateral aspects of the midface combined scapula grafts are useful. The thin scapula bone can be used for reconstruction of the orbital floor and the infraorbital rim, whereas partially de-epithelized aspects of the parascapular skin pedicle are used for augmentation of the skin (Fig. 30.**7**). Another aspect of the parascapular flap or an additionally harvested scapula flap can then be positioned caudally, to form the oral lining of the alveolar process of the maxilla.

Volume augmentation in the lateral midface with a de-epithelized parascapular flap can also be combined with a scapula bone graft used for reconstruction of parts of the zygoma, as for example the zygomatic arch. Therefore hemifacial microsomia patients may be suitable candidates for soft tissue and bone reconstruction with scapula grafts.

Conclusion

Indications for the use of scapula grafts are isolated soft-tissue defects or combined defects with a predominant soft-tissue problem. The grafts can be used for reconstruction of posterior aspects of the mandible and the ascending ramus with additional intraoral or extraoral soft-tissue defects. Scapula grafts are the grafts of choice for reconstructing combined defects in the maxilla or midface.

compared to Co–Cr particles (Haynes *et al.*, 1993). The main corrosion product, the dioxide rutile, is almost insoluble in body fluids. Thus, it accumulates in lymph nodes, liver, spleen, bone marrow, and brain (Case *et al.*, 1994). Titanium debris appears as grey discoloration at the implantation site (Lalor *et al.*, 1991; Scales, 1991) and may be entrapped by collagen fibers after unsuccessful degradation by macrophages (Schliephake *et al.*, 1993, Nakamura, Takenoshita, and Masuichiro, 1994). However, titanium particles are also transported from the site of origin by the blood (Hillmann and Donath, 1991) and the lymphatic route (Onodera, Ooya, and Kawamura, 1993; Weingart, Steinemann, and Schilli, 1994). Titanium debris is not inert (Case *et al.*, 1994). In the lymph nodes, sinus histiocytosis (Albores-Saavedra *et al.*, 1994), necrosis and fibrosis (Case *et al.*, 1994) and a symptomatic granulomatous reaction in liver and spleen have been demonstrated (Peoc'h *et al.*, 1996).

Toxicity of the alloyed metals may be a reason for plate removal. However, toxicity depends on dosage and the systemic doses of aluminum and vanadium resulting from facial plates are supposed to be low. However, toxic effects are cumulative. In renal insufficiency especially, removal should be mandatory.

Inflammatory Response

Inflammatory complications like peri-implantitis, aseptic loosening of hip replacement, or persistent inflammation of skin-penetrating implants occur in various fields of titanium application (Jacobson *et al.*, 1987). The primary cell type to react against titanium is the macrophage (Anderson and Miller, 1984). Macrophages have been shown to react to titanium particles in phagocytable sizes, with activation of lysosomal enzymes and a partial degradation (Elagi, Vérnon, and Hildebrand, 1995; Wooley, Nasser, and Fitzgerald, 1996). Activated macrophages release inflammatory mediators. Bone-resorbing cytokines IL-1δ, IL-6 and TNF-ĩ were demonstrated after stimulation of macrophages with particles, and Ti–AL–V was more potent than cpTi (Shanbhag *et al.*, 1995). Titanium ions also enhanced the release of bone-resorbing cytokines and inhibited bone-protecting cytokines (Wang *et al.*, 1996a). Co–Cr particles result in early cell death after phagocytosis, whereas the less toxic Ti–Al–V particles lead to an inflammatory response (Haynes *et al.*, 1993). Thus, titanium particles may exhibit inflammatory effects because they are nontoxic and insoluble. Clinically, in the maxillofacial region a chronic inflammatory response was demonstrated immunohistochemically in retrieved tissue (Katou *et al.*, 1996). Granulation tissue, bone resorption or loose hardware was found in 50% of maxillofacial patients (Kim, Yeo, and Lim, 1997). Thus the argument of macrophage activation and inflammatory response supports elective plate removal.

Sensitivity to titanium

Titanium is used extensively as an ingredient in house paints, in paper, as a food additive, in cosmetic articles (Moran *et al.*, 1991), in ointments or topical dental fluorides (Lalor *et al.*, 1991; Charvat *et al.*, 1995). Sensitivity to titanium is not common, in contrast to nickel and chromium (Rudner, Clendenning, and Epstein, 1975; Goh, 1986; Haug, 1996). However, titanium from corrosion products does bind to cells and proteins and can stimulate immunologic responses (Maurer, Merritt, and Brown, 1994; Ikarashi *et al.*, 1996). Titanium pacemaker rejection (Peters *et al.*, 1984; Verbov, 1985; Abdallah, Balsara, and O'Riordan, 1994), sensitivity to titanium joints (Black *et al.*, 1990, Lalor *et al.*, 1990, Merritt and Rodrigo, 1996), asthma (Breton, Louis, and Garnier, 1992), and reactions to skin-penetrating titanium implants (Holgers *et al.*, 1992) are reported. Titanium sensitivity was correlated to aseptic loosening of joint replacement (Lalor *et al.*, 1991; Merritt and Rodrigo, 1996). T-lymphocyte activation adjacent to maxillofacial titanium plates has been observed (Torgensen *et al.*, 1995; Katou *et al.*, 1996).

Contact sensitivity to aluminum (Dwyer and Kerr, 1993; Lopez *et al.*, 1994) and vanadium (Motolese *et al.*, 1993) has occasionally been reported in the literature. Vanadium sensitization was reported in a group of patients with hip replacement (Cancilleri *et al.*, 1992).

Contact sensitization is a slow, type IV reaction and takes several months to develop. Studies monitoring contact sensitivity to metal appliances could not show sensitization before 6–12 months, by when the device usually has fulfilled its function (Merritt and Rodrigo, 1996). Contact sensitization may be an argument for elective plate removal, since the prevalence of sensitivity depends on the number of exposed individuals and the duration of exposure (Merritt and Rodrigo, 1996).

Carcinogenity

Associations of soft tissue malignancy (Goodfellow, 1992) or hepatopoietic malignancy (Gillespie *et al.*, 1991; Visuri and Koskenvuo, 1991) with metallic implants have been reported. However, cases are rare compared to the number of incorporated metallic implants (Haug, 1996). Experimentally, nickel alloys evoked sarcomas in rodents (Takamura *et al.*, 1994). It is advocated that nickel-containing alloys (stainless steel) should be removed (Haug, 1996). Tumors in the vicinity of titanium implants are comparatively rare (Fraedrich *et al.*, 1984, Friedman and Vernon, 1983) and have not been induced experimentally. Cancerogenicity seems not to be an argument for plate removal in the maxillofacial region (Haug, 1996).

Infection

Metal hardware may serve as a foreign body, prone to infection through blood-borne bacteria, and may act as a focus for immunologic disorders in young patients (Dobbins, Seligson, and Raff, 1988). A reason for infection around titanium plates may be the inhibition of T and B cell proliferation by titanium, cobalt, and chromium mediated by IL-2 and IL-6 (Wang *et al.*, 1996b). Titanium-induced dysfunction of alveolar macrophages to kill *Staphylococcus epidermidis* may be another reason (Giridhar, Myrvik, and Gristina, 1995). Plates have to be removed once an infection is clinically evident. In contrast to orthopaedic surgery, delayed infection and septic loosening of implants is not an important clinical issue in maxillofacial surgery.

Diagnostic and Therapeutic Radiation Scattering

MRI and CT imaging artefacts of titanium plates are significantly reduced compared to Vitallium and stainless steel plates (Eppley *et al.*, 1993; Fiala, Novelline, and Yaremchuk, 1993; Fiala *et al.*, 1994). Scattering of diagnostic radiation by titanium implants seems not to be harmful (Rosengren *et al.*, 1993). Back scattering of therapeutic radiation has been a problem. Radiotherapists, however, have managed this problem and found solutions (Gullane, 1991; Castillo *et al.*, 1988).

Stress Shielding

Stress shielding by plates, leading to localized osteoporosis and risk of refracture after plate removal, is a problem in orthopedic surgery (Frankel and Burstein, 1968; Uthoff, Boisvert, and Finnegan, 1994) and has been demonstrated experimentally in maxillofacial surgery (Kennady *et al.*, 1989). Based on the absence of clinical reports refracture due to stress shielding does not seem to be an issue in facial fractures (Haug, 1996).

Conclusion and Ethical Considerations

Toxic effects of aluminum and vanadium, sensitization to metals, a proliferative and inflammatory stimulus and widespread dissemination of titanium debris in the body are the main arguments for elective plate removal especially in young individuals. Corrosion of titanium may be enhanced considerably by hydrogen peroxide released from activated macrophages.

However, under certain conditions characteristics of biocompatibility may manifest differently (Katou *et al.*, 1996). In dental implantology, titanium is encapsulated by bone. Thus, interaction of titanium and the organism is reduced. In orthopedic devices the quantities of metal and production of wear particles usually differ from maxillofacial plates. Thus, results from dental implantology and orthopedic surgery do not easily transfer to maxillofacial plating.

The following statement was issued during the 1991 Strasbourg Osteosynthesis Research Group meeting.

> A titanium plate which is intended to assist the healing of bone becomes a non functional implant once this role is complete. It may then be regarded as a foreign body. While there is no clear evidence to date that a titanium plate causes any actual harm, our knowledge still remains incomplete. It is therefore not possible to state with certainty that an otherwise symptomless titanium plate left *in situ* in the long term is harmless. The removal of a non functioning titanium plate is desirable provided that the procedure to remove the plate does not cause any undue risk to the patient (Black, 1988; Bos, 1993).

In many countries, the need for a general anesthetic to remove these plates or the need to open old incisions constitutes just such an 'undue risk to the patient.'

32 Complications: Causes and Management

Klaus Louis Gerlach and Hans-Dieter Pape

Introduction

Complications connected with miniplate osteosynthesis are more frequently observed after treatment of mandibular fractures than in other situations. The most important complications include wound healing, for example suture dehiscences, abscess formations, osteomyelitis and pseudarthrosis. The main factors predisposing to these are delayed treatment, missing perioperative antibiotic treatment, and insufficient fracture stability. Long-term follow-ups indicated that some errors in technique and management led to certain complications, which were seldom seen by experienced surgeons (Gerlach *et al.*, 1985; Champy and Blez, 1992).

Suture Dehiscences

A breakdown in the intraoral closure commonly occurs between the fourth and eighth postoperative day after treatment of mandibular fractures. This complication is encountered mainly in the posterior region where the plate was located close to the external oblique ridge. In unselected series the incidence of this complication was reported between 2.7% and 12% after osteosyntheses (Cawood, 1985; Gerlach *et al.*, 1985; Champy *et al.*, 1986b; Champy and Blez, 1992).

Suture dehiscences were more frequently found if there had been an undue delay between the time of trauma and the time of operation; they can also occur following an inappropriate incision within the region of the attached gingiva. The incision line should be placed 5 mm below the attached gingiva or on the marginal rim. Preexisting mucosal tears and poor oral hygiene were other possible factors contributing to wound dehiscence. In such cases, after removal of the sutures and wound cleaning with 1.5% hydrogen peroxide, the wound is dressed with a iodoform Vaseline pack. A secondary suture is not necessary. An unimpaired bony union is ensured by normal open-wound treatment.

Infection

Postoperative infections with abscess formations are also commonly observed in those patients whose treatment had been delayed for some days following trauma and who received no antibiotic prophylaxis. This became obvious when, with the decrease of the preoperative time interval, the frequency of abscess formation also diminished from 6.6% to 3.4% (Gerlach I, 1985; Champy and Blez, 1992). In larger series, the quota of postoperative infections was reported between 1% and 6% (Cawood, 1985; Champy, 1986b; Nakamura, Takenoshita, and Masuichiro, 1994; Tuovinen *et al.*, 1994; Reinhart *et al.*, 1996; Kakoschke, Mohr, and Schettler, 1996; Pape *et al.*, 1996).

As well as the early treatment of fractures, a perioperative antibiotic treatment is recommended to avoid infections. In a randomized prospective study 200 patients with a different therapeutic regime were compared (Gerlach and Pape, 1988). Patients received antibiotics prophylactically for differing periods; 50 patients for 1 day, 49 patients for 3 days, 50 patients a one shot prophylaxis, and 51 patients had no antibiotics. The first administration of a combination of mezlocillin and oxacillin was given in all cases 30 minutes before the operation. Infections were found in 23 of 200 patients. The analysis of the examined groups indicated 15 infections in the control group and one, three and four infections, respectively, in the different prophylaxis groups. A 1 day perioperative antibiotic treatment is recommended.

If an abscess develops, incision and drainage generally lead to a normal bone healing. Usually the plates can be retained *in situ*. Only in cases of delayed infections after 1 or 2 months postoperatively, the osteosynthesis material should be removed if it does not assure immobilization. This is usually caused by poor reduction or poor stabilization from badly placed plates. If bony union is insufficient, intermaxillary fixation becomes necessary.

Osteomyelitis

Osteomyelitis of the fracture site is the most serious form of infection but this complication seldom occurs. All series reported incidences between 0.2% and 1% only (Champy and Blez, 1992).

In those cases, inadequate immobilization of the fragments was the cause. For example, the use of only one miniplate in the region anterior to the canines, fracture fixation with only a single screw in one of the fragments and application of plates outside the correct osteosynthesis tension line. Furthermore these patients often failed to keep outpatient appointments. In case of an osteomyelitis, the removal of the plate and a period of intermaxillary fixation following incision and drainage of the infected fracture line is necessary. Bone healing usually follows this treatment.

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